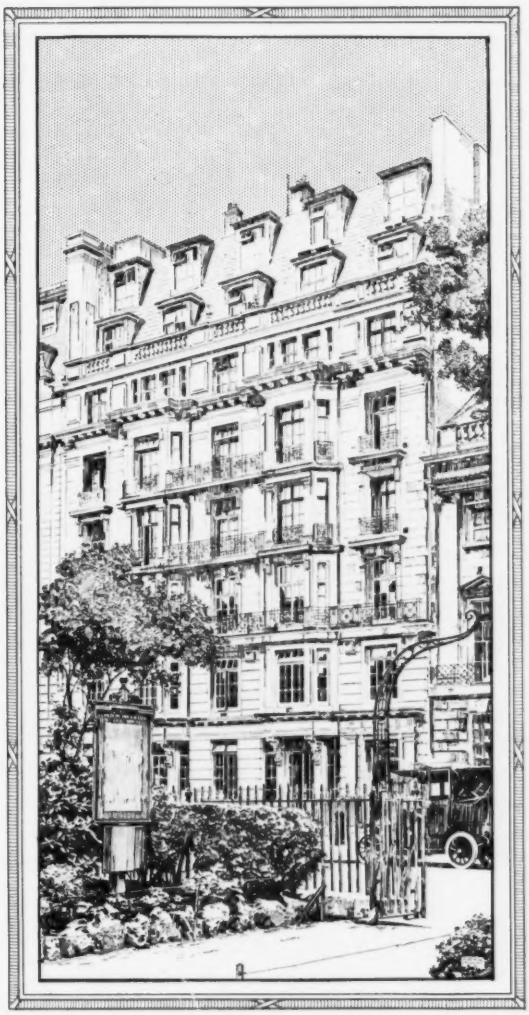
The ENGLISH ELECTRIC JOURNAL



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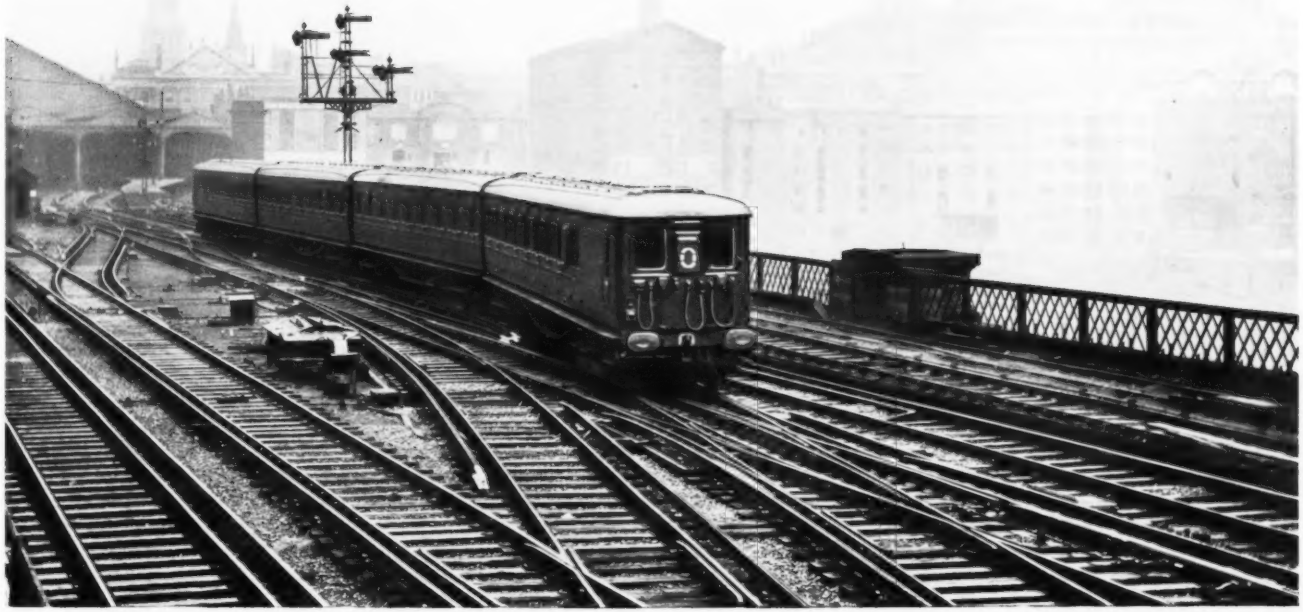

ELECTRIFICATION OF THE SOUTH-EASTERN SECTION OF THE SOUTHERN RAILWAY. A 4-COACH TRAIN ENTERING ST. PAUL'S STATION.

The English Electric Journal

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2.

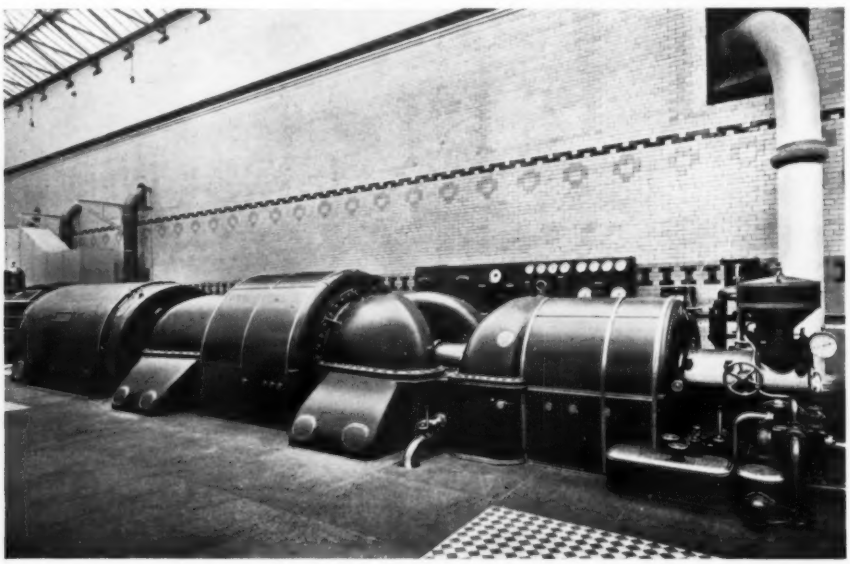
EDITORIAL.

It is sometimes said that we British, as a nation, are too given to self-depreciation, and it may be that we are apt to forget that to British engineers and scientists the world owes the majority of the great discoveries and inventions of the past hundred years. The steam engine, the steam turbine, the locomotive, the steamship, the oil engine, the weaving loom and most textile machinery, all owe their origin and early development to British ingenuity and, in the electrical field, we find the telegraph, the first principles of dynamo machinery, the microphone, the incandescent lamp, and a great part of the pioneer work in the vast field of wireless research, all the work of our countrymen. In short, no country in the world has been the home of so many original thinkers in the engineering field as has Great Britain, and it is indeed a strange trait in our national character that leads us at times to overlook the great record of our past, and to compare ourselves unfavourably —and to allow others so to compare

us—with rival nations in the field of engineering work.

It may be true that in the past we have been too prone to let others develop our discoveries and inventions, and to reap the material benefits accruing from our genius, and it may also be true that other countries have been, shall we say, more skilful in pressing forward their commercial campaigns for the capture of the world's markets, and that they have done this with machinery and other products which have been really the offspring of British brains. It is a question if we do not still lack the advertising power of some of our most formidable rivals; if we are not behind in that self-assertiveness, which, distasteful as it may be to those imbued with British tradition, appears, for good or evil, to be a real factor in success at the present day. With other nations clamouring the merits of their wares, we British cannot afford to be silent, and to hearten us in this advertising campaign, let us never forget the great Engineering Record of our race. None of our rivals has such a record, and we have to look to it that in its Market Places the world is made fully cognizant of this great truth.

After these remarks, which may not be out of season at the present time, but little space is left for comment on the articles that follow. We think, however, that these speak for themselves and will serve as a record of a few of the large contracts recently carried out by the Company and also of progress in standard switchboard construction and in rolling mill control.



20,000 K.W., 3,000 R.P.M. "English Electric" Steam Turbine recently set to work in a Municipal Power Station.

Traction Motors and Sub-station Equipment for the Southern Railway.

Since the last issue of this Journal the first section of one of the most important railway electrifications yet carried out in this country has been inaugurated and has passed into routine working. We refer, of course, to the electrification of the first part of the suburban lines of what was formerly the South-Eastern and Chatham Railway. It will be recalled that the complete scheme for this electrification provides for the conversion to electrical working of all the lines within about thirty miles of the Metropolis, of which total the portion up to fifteen miles radius has been proceeded with first and an initial instalment has just been set to work.

The system adopted is direct current at 660 Volts, led to the trains by a conductor rail, the running rails being used as a return. Power is delivered in bulk from the Deptford Station of the London Electric Supply Corporation to the Railway Company's main distributing centre at Lewisham in the form of a three-phase, 25-cycle supply at 11,000 Volts. From Lewisham, distribution is made to the various substations along the line.

The Southern Railway placed contracts with The English Electric Company for the supply and erection of the following: 508 Railway Traction Motors, each of 300 H.P.; 19 complete Rotary Converter Equipments with Switchgear for seven substations.

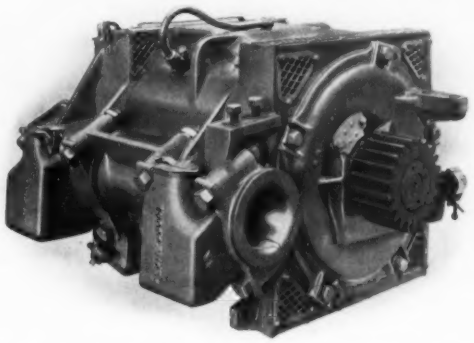


FIG. 1. D.K. 77 SELF-VENTILATED RAILWAY MOTOR: 300 H.P.

The D.K. 77, 300 H.P. motor adopted for the system, and illustrated in Fig. 1, is amongst the largest self-ventilated, direct-current traction motors yet constructed, and embodies in its design the knowledge gained from long experience in the manufacture and operation of motors for electric railways in all parts of the world. Perhaps the most striking feature of these motors is the solidity of their design and construction, a characteristic of the utmost importance in view of the severe conditions imposed by heavy suburban railway service.

Every detail down to the smallest part is thoroughly sound mechanically and has whatever factor of safety long experience in this class of work has shown to be necessary. All the main castings are of steel and the bearings are of generous proportions; mica insulation is used for the armature and field windings; every fastening is securely locked against any slackening through vibration.

Two motors are mounted on one truck of each motor coach and drive on to the axles through single-reduction spur gearing which gives a ratio of 59 to 21. The motor suspension is of the "Nose" type with the interposition of a rubber shock absorber for cushioning purposes.

The motors are four-pole machines fitted with auxiliary poles in order to give good commutation at all loads. Cast steel of high permeability is used for the magnet frame, which is of the box pattern with suitable openings cast in for ventilation and commutator inspection. The ventilating openings are covered by substantial cast grids and the large inspection openings which give access above and be-

low the commutator are closed by pressed steel covers provided with quickly operated toggle type fasteners.

There are two separate steel castings in the form of end-shields with the armature bearings in the centre, and these are bolted to machined spigotted facings at the ends of the magnet frame. The caps of the axle bearings are also separate castings. The bearing bushes themselves consist of special bronze lined with high-grade babitt metal suitably grooved for the distribution of the oil. In the case of the armature bearings each bush is in one piece, but the axle bearing bushes are split obliquely to permit the motor to be removed from the truck. The length of axle between the two bearings is enclosed by a dust shield of sheet metal.

Lubrication of both sets of bearings is arranged upon the method usually employed in traction motors. The oil is conveyed to the shaft by means of tightly rammed wool waste packing which is in direct contact with the side of the journal through an ample " window " in the bush, and draws oil from a reservoir of sufficient capacity for two or three weeks normal running.

With regard to the field system, the chief points of interest are the heavy insulation and the care taken in manufacture and assembly to ensure the longest possible life for the field coils. As already mentioned, mica insulation is employed both for the main and for the auxiliary field coils, and they are treated in a very thorough manner in order to render them impervious to moisture. The coils are clamped between the pole shoes and the magnet yoke by means of a pressed steel spring at the yoke end and a brass end plate at the shoe end. Any shrinkage is thus taken up automatically and the coils are always held rigidly in place and protected from injury in the event of armature trouble. The care which they deserve is given to the connections of the field coils, which are clamped and sweated solid so that there is no risk of overheating. Moreover, any tendency of the leads to fracture is reduced by leaving the longest possible length flexible.

FIG. 2. FITTING MOTORS ON A MOTOR COACH TRUCK.

Coming now to the armature, the same solid construction is found as in the fixed portions of the machine. The shaft is made from best quality forged steel, ground to gauge, and the journal surfaces are rolled to ensure the maximum life of the bearing bushes. The core plates are supported on a cast steel spider between end plates of the same material, and the commutator is built on its own cast steel spider, which is mounted on and keyed to an extension of the armature spider. In this way the shaft can be removed or replaced without disturbing the armature windings or commutator. Former-wound coils with mica insulation are used, and as in the case of the field coils, a process of impregnation and baking is followed until the windings are as damp proof as it is possible to make them. The commutator and brush gear are very solidly built and are easily accessible through the inspection covers provided in the frame. All parts of the motor are machined and finished to gauge or jig, and the manufacturing processes adopted aim at securing the highest degree of interchangeability of similar parts.

As already mentioned, the gears are of the single-reduction spur type, each wheel and pinion being a single forging of selected high-grade steel cut in special machines. The pinions are ground after the heat treatment, but the teeth of the spurwheels are not cut until after the heating process. The gearcase is very substantial, and consists of two halves pressed out of sheet steel 3/16th in. thick; these are rigidly bolted together and the complete case supported from three heavy lugs provided on the motor frame casting.

The views in Figs. 1, 2 and 3 show the chief points in the design of the motor frame, and

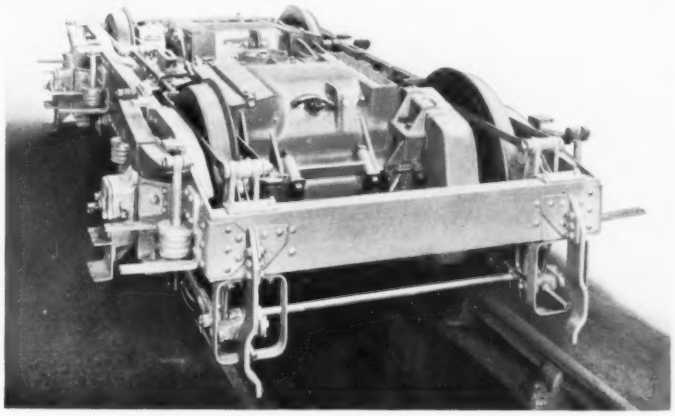


FIG. 3. MOTORS INSTALLED ON A TRUCK.

illustrate clearly the ventilation openings, the commutator inspection covers and the arrangement of the axle bearings; they also convey an indication of the robust character of the machines generally, and the care and finish which has been bestowed on all important details. Fig. 2 shows very clearly the method of assembling the motors in the trucks, and the view of the motor already in place shows how the leads are brought out through metallic flexible piping.

The nineteen 1,500 K.W. rotary converters supplied by this Company are distributed as follows: Lewisham four machines, Cannon Street, Loughborough and Shortlands each three machines, Nunhead, Victoria and Grove Park each two machines. In addition to the converters themselves the complete "English Electric" equipment in each substation consists of: (1) 1650 K.V.A. transformer for each converter to reduce the pressure from 11,000 Volts to that required at the sliprings, (2) E.H.T. switchgear in cellular type structure for controlling the incoming feeders, and also sub-feeders to other distribution centres, (3) Panel type control board of slate construction mounted in the converter room and carrying all the operating handles for the E.H.T. switchgear, as well as the D.C. switchgear, and all necessary instruments. Mounted at the side of each converter is a starting pillar to which detailed reference will be made later.

Fig 4 shows a group of the rotaries at the Stafford Works of the Company. These machines are particularly massive and pleasing in appearance, and the absence of a pony motor makes them extremely compact. The normal output is 1,500 K.W., but the design is very liberal, and they are able to give an overload of 25 per cent. in excess of this continuously without the temperature rise in any part exceeding 45° C. Further, in order to comply with the severe conditions which are always associated with traction work the machines are rated to withstand short-time overloads up to four times full load momentarily. The rotaries are 6-pole machines and therefore run at 500 r.p.m.

The 11,000 Volt supply enters the lower floor of the substation and is controlled by switch-

gear housed in stonework cells on the same level. Each phase has its own oil circuit-breaker in a separate cell, and the three breakers for any circuit are connected by a way-shaft and operated by a single toggle mechanism and connecting rod.

The oil circuit-breakers are "English Electric" standard O.K.C. type which is liberally designed for dealing with the most severe fault conditions which may be expected to arise. A special feature of the design is the way in which the space above the oil is sub-divided so that two separate air spaces are located directly above the contacts. These air spaces are comparatively small, and have the effect of keeping the gas bubbles at a high pressure, and the oil in close contact with the arc; they are not directly connected, but each air space leads through a baffle plate into a single expansion chamber which, in turn, is connected to the air outside the breaker cell by means of a vent pipe.

It is the function of the baffles to separate the hot gas from the air in the expansion chamber and allow mixing to proceed only gradually, thus guarding against the possibility of an explosion and preventing oil throwing. The aggregate volume of the air spaces and the air chamber is sufficient to provide an adequate air cushion and prevent shock when the switch opens under a heavy current.

A general view of a cellular switchgear structure is shown in Fig. 5, in which the operating rods can be seen passing up through the floor to the control panels on the upper floor of the substation. Fig. 6 shows another view of the same cellwork with one of the enclosing doors partly open to show the interior construction.

An interesting feature of all the "English Electric" substation equipments is the employment of special auxiliary transformers to supply the potential circuits for the whole of the switchgear, except certain main meters.

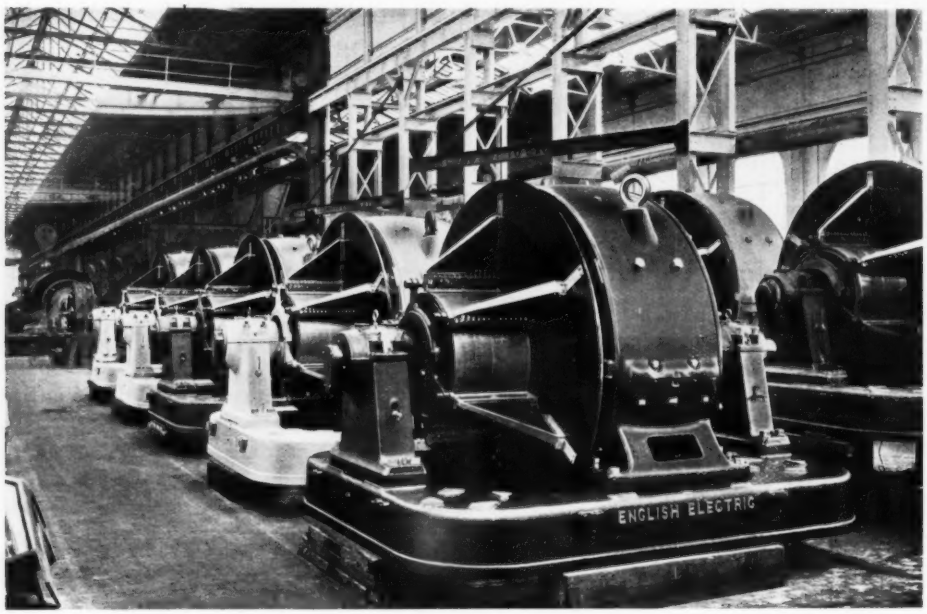


FIG. 4. GROUP OF 1,500 K.W. ROTARY CONVERTERS AT STAFFORD WORKS.

These transformers have been manufactured in the Transformer Department of The English Electric Company and are protected by " English Electric " oil-immersed switch-fuses, in which the fuse is mounted between two contacts attached to the inside of a hinged lid. When the lid is closed these contacts engage with fixed contacts in the oil tank, but on opening the lid the fuse and moving contacts are clear of the oil and entirely disconnected from the circuit. The fuse wire is comparatively short and is carried between spring-loaded plungers which are drawn rapidly apart when the fuse blows, and thus give a long clear break with the use of an extremely small amount of metal in the fuse.

Where separate potential transformers are provided for special meters, they are accommodated in individual chambers and provided, in addition to the usual high-tension fuse, with isolating switches having limited resistances incorporated in the switch blade. The arrangement of these transformers in the cellwork is illustrated by Fig. 7.

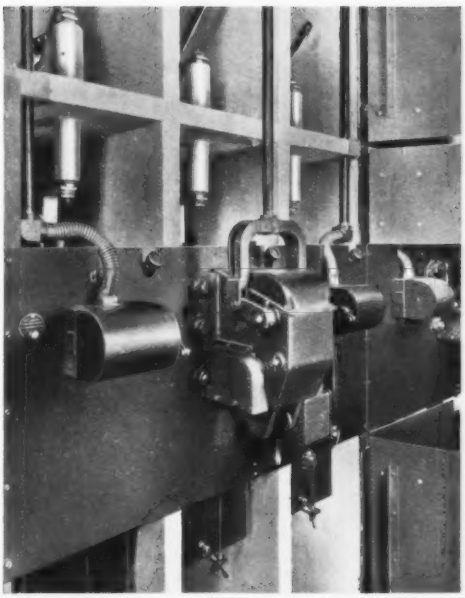


FIG. 6. 11,000-VOLT OIL CIRCUIT-BREAKER CELLS AND OPERATING GEAR.

FIG. 5. BACK OF E.H.T. SWITCHGEAR STRUCTURE.

From the E.H.T. switchgear the supply passes to the step-down transformers, each of which is housed in a cell with solid brick walls on three sides, but exposed to the open air on the side nearest the outside wall of the substation. Protection is afforded on this side by a heavy iron grille with a gate through which access can be obtained.

The transformers contain many interesting features illustrative of standard " English Electric " practice in this class of apparatus. They are of the oil-immersed, self-cooled core type with a normal rating of 1,650 KVA., but are capable of working on a continuous overload of 25 per cent. without the temperature rise exceeding 60° C. Their general construction is shown clearly in Fig. 9, and it will be noticed that in the design of the tank an arrangement of tubes has been introduced

which is a departure from that usually adopted. The tank itself has semi-circular ends from which the tubes radiate symmetrically so that they are distributed over the whole peripheral surface uniformly. The round-ended tank is stronger mechanically than one with square corners, and permits more cooling tubes to be fitted; at the same time the absence of corners results in economy of oil and the promotion of better circulation throughout the active parts of the transformer. It will be agreed also that the appearance of the apparatus is considerably improved. As will be seen from the illustration, the transformers have been provided with calcium chloride breathers working in conjunction with oil expansion vessels to ensure dryness of the oil and to prevent sludging.

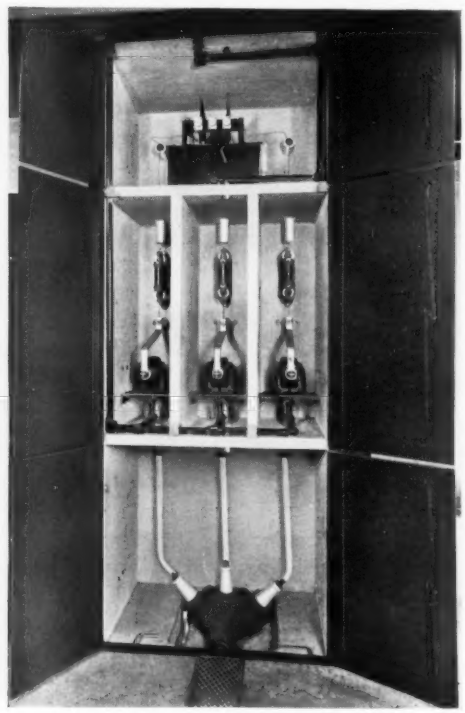


FIG. 7. INSTRUMENT TRANSFORMERS IN E.H.T. SWITCHGEAR CELLS.

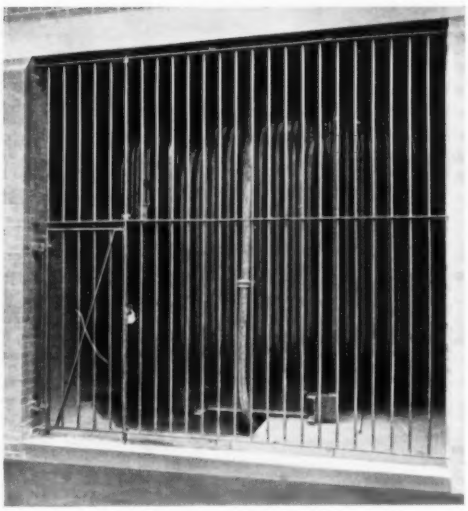


FIG. 8. 1,650 K.V.A. TRANSFORMER IN SUBSTATION CELL.

Fig. 9 shows one of the transformers lifted out of its tank and gives a clear idea of the arrangement of the cores, windings and connections; it will be seen that the latter are arranged in a manner which is simple and thoroughly mechanical. Great care is taken in the manufacturing process to eliminate the shrinkage of the coil columns, but the transformers are fitted with a special spring washer device to take up any small contraction which may occur in service, and ensure that no movement of the coils can occur in the event of a sudden overload or short circuit. By suitable concentric arrangement of the high and low-tension windings the transformers are given a reactance of about 10 per cent.

Next in order are the rotary converters each controlled by its own starting pillar. Attention has already been drawn to the absence of pony motors, and instead of using that method of starting, the converters are designed to start from a low-voltage tapping on their associated transformers. This starting method is self-synchronising, simple and expeditious, and the

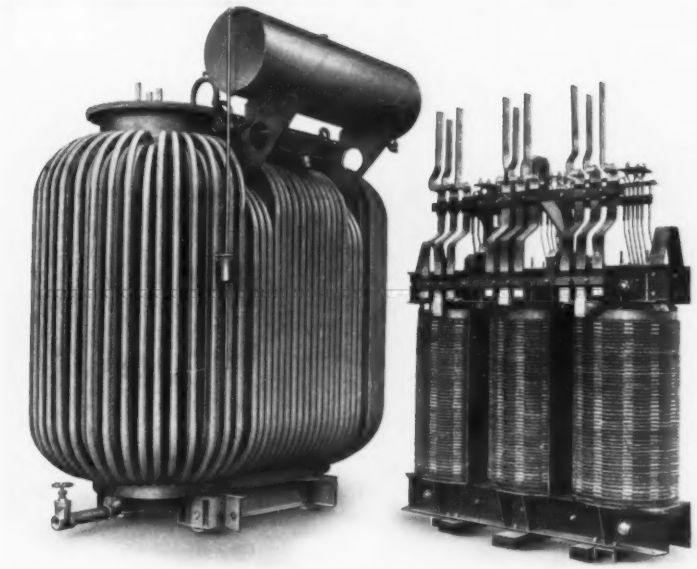


FIG. 9. 1,650 K.V.A. TRANSFORMER AND TANK.

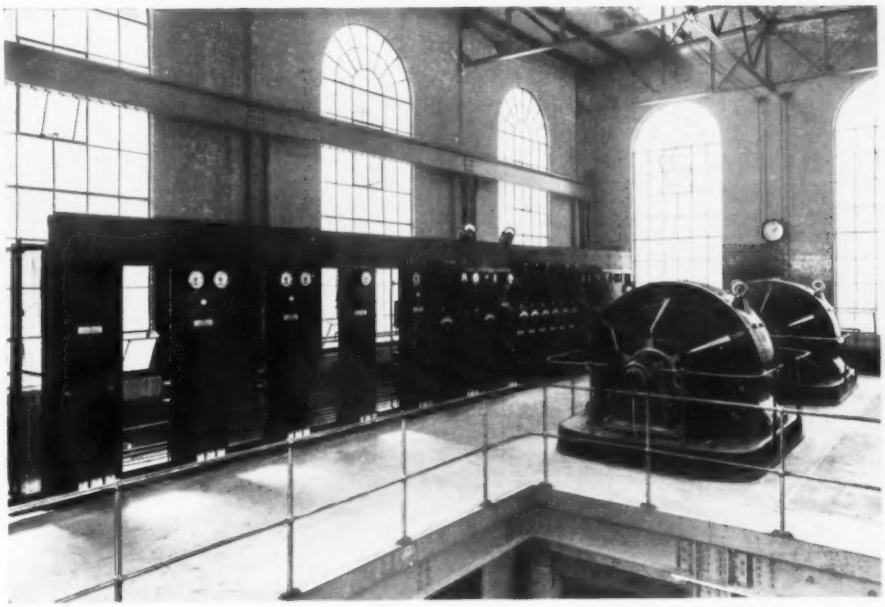


FIG. 10. 1,500 K.W. ROTARY CONVERTERS AND CONTROL SWITCHBOARD IN SUBSTATION.

machines can be run up and paralleled on to the D.C. busbars in less than 45 seconds—an advantage of great value on a traction service. In designing the machines full consideration was given to the starting requirements, and the current is kept down to a conservative value which compares well with other methods. Smooth acceleration is ensured by means of a very rigid and ample damping winding, and by special arrangements of the armature slots and conductors, and there has been no necessity to use either a field-splitting switch or a brush-lifting device at the commutator end.

It will be noticed in the illustrations, Figs. 4 and 10, that a large circular barrier of insulation is fixed between the armature and the commutator, and each line of brushes is shielded on both sides by plates of insulation in order to protect the armature and brushgear in the event of a flashover taking place due to heavy short circuits on the line.

Good commutation under severe and sudden overloads, and freedom from flashover are naturally of prime importance in converters for this class of duty, and the machines in question are fitted with the special form of commutation pole developed by The English Electric Company, which has a high reluctance and enables a very stiff commutating field to be obtained without undue magnetic leakage; the good behaviour of the machine is further assisted by making the commutator risers of high resistance material. To ensure that the mechanical conditions for commutation shall be as favourable as possible, the armature and commutator are balanced with the greatest care and provided with means for adjusting the balance similar to that used on turbo-generators. Freedom from vibration is still further enhanced by making the shaft very rigid and keeping the distance between the bearings as short as possible. In designing the moving parts of the D.C. brushgear special care has been given to avoiding unnecessary weight in any of the parts so as to reduce their inertia to a minimum.

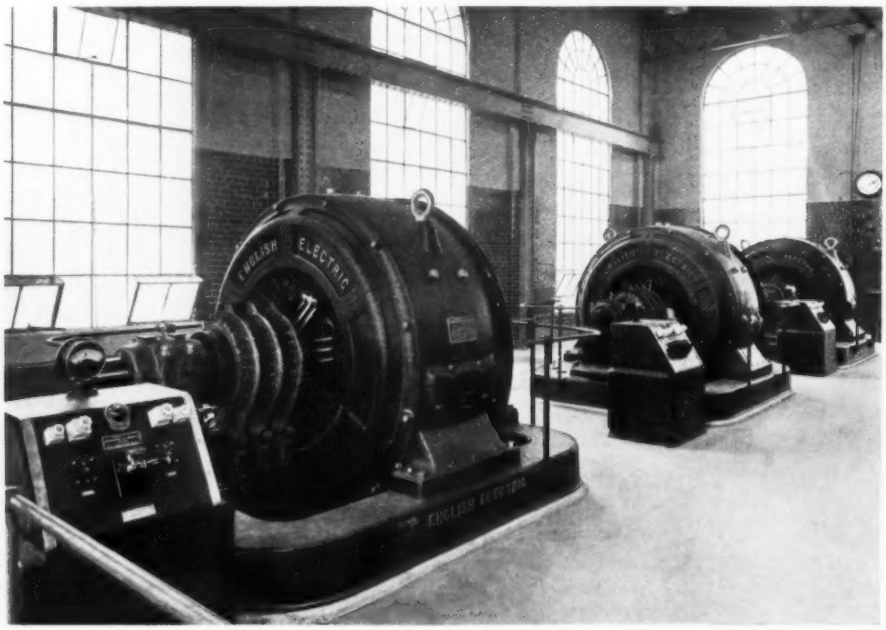


FIG. 11. THREE 1,500 K.W. ROTARY CONVERTERS AND TAP STARTING PILLARS.

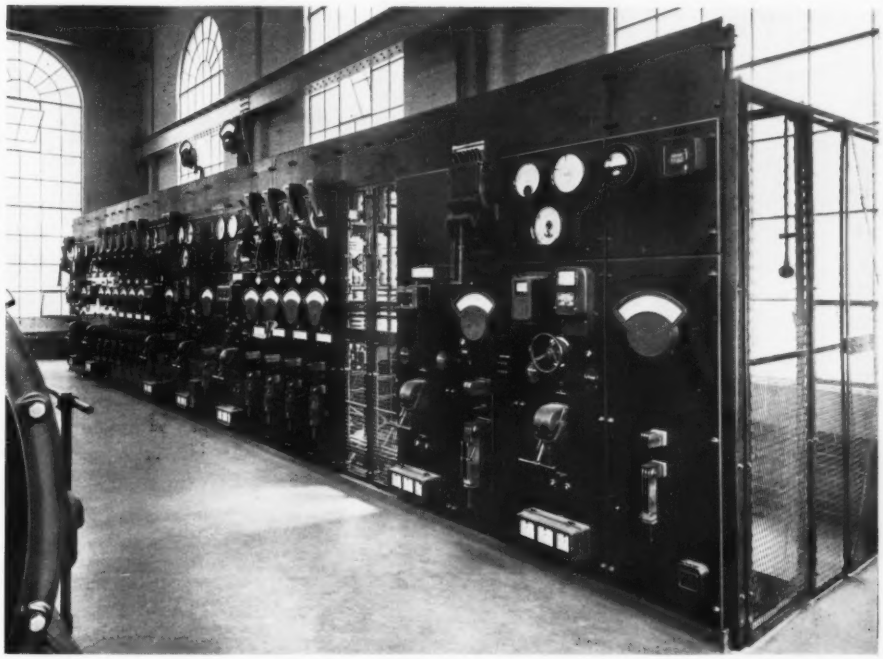


FIG. 12. TYPICAL CONTROL SWITCHBOARD FOR E.H.T. FEEDERS AND ROTARY CONVERTERS.

There is no brush rocking device on these machines. The best position for the brushes is found on test and no movement is necessary from no load to the highest momentary overload. The rocker ring is dowelled to the frame, thus locating the brushes permanently and guaranteeing the same position after any subsequent dismantling and re-erection. Another important point is the maintenance of the correct cylindrical form of the commutator under all conditions of temperature or mechanical stress. This is ensured by a method of assembly which allows for lateral and longitudinal expansion without permitting distortion to occur.

The ventilation of all parts of the machine has been given careful attention, and the design ensures the flow of a large volume of cool air from the slipring end, through the machine and out over the surface of the commutator. The cooling air is directed by means of shrouds fitted at the slip-ring end of the frame and is impelled by the fan action of the distance pieces in the ducts of the armature core. The coil ends of the armature winding are arranged to form an open mesh with a large cooling surface, and the outer ends of the commutator segments are specially shaped to form fans which promote air circulation and also to act as arcing tips. As the illustrations show, these machines are constructed with bearing pedestals which bring the axis of the armature and magnet frame well above the ground line. This arrangement is favourable to good cooling as it avoids a deep pit in the foundations where there is always a tendency for the air to remain stagnant.

For the purpose of rotating the armature when the commutator or sliprings have to be ground, a 12 H.P. 3-phase portable motor is provided in each substation, and this is belted

to a detachable pulley which is readily fitted to one end of the converter shaft.

The starting pillars used for the rotary converters are clearly seen in the illustrations. Each pillar is entirely self-contained, and consists of a cast-iron framing with sheet-steel cover plates which entirely enclose all live parts. On the right-hand side is the main starting lever and in the centre of the desk-top, the field switch lever; the instrument is a centre-zero voltmeter. The whole operation of starting requires very little skill and occupies less than a minute.

One low-voltage tap only is required for starting these rotaries, and the starting operation consists of two main movements, that is to say, moving the starting lever from the " off " to the " starting " position where the rotary is connected to the low-voltage tap, and then the final throw into the running position in which full voltage is applied to the sliprings. A mechanical catch prevents the operating lever from being thrown directly from " off " to " running," and an interlock—also mechanical—between the field switch and the tap starting switch ensures that the field switch is " off " before the tap starter can be moved from its "off" position. The last-named interlock also makes it necessary to close the field switch prior to moving the starting lever to the " running " position. When the starting lever is in the final running position, the field switch is locked closed.

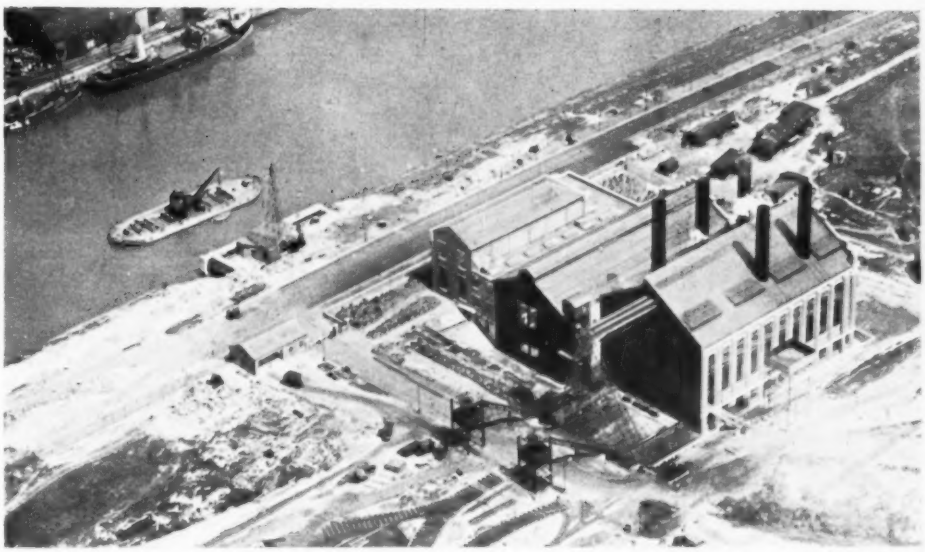
An electrical interlock is fitted between the oil breaker on the switchboard and the starting pillar, to ensure the tap starter being in the " off " position before the breaker is closed. The A.C. breaker and D.C. breaker can be tripped from the starting pillar by means of push buttons.

The control switchboard in each substation carries all the operating levers for the remote mechanically-operated oil circuit-breakers, the D.C. switchgear and the instruments for all the A.C. and D.C. circuits. A view of a typical control board for a substation containing three rotary converters is shown in Fig. 12. The D.C. breakers are standard " English Electric " S.K.A. type, of 4,000 ampere size on the rotary converter panels and 2,000 ampere size on the feeder panels. They are of the free handle, laminated brush design with metal arcing horns, and are very substantially constructed with special regard to the requirements of heavy traction service.

Aluminium has been employed for the busbars and connections, and also for the connections between the rotary converters and the tap starting pillars; where necessary they are specially supported and anchored to withstand the stresses produced by heavy currents.

Two alarm bells are provided in each station to give warning of the opening of any D.C. or A.C. circuit-breaker respectively.

Electricity Supply Developments at Preston.



Aerofilms Limited.

FIG. 1. BIRD'S-EYE-VIEW OF THE RIBBLE POWER STATION.

The Ribble Power station, opened by Sir John Snell, G.B.E., Chairman of the Electricity Commission, on July 22 last, is destined to play an important part in the electricity development of the country. By virtue of its position in one of the great industrial districts it is favourably situated for linking up with other large supply stations; in fact, arrangements are already well advanced for interconnection with the Lancashire Electric Power Company's system and with the Whitebirk station* of the Blackburn Corporation. It is anticipated that comprehensive planning of the electricity supply on these lines will lead to important savings in production costs, and as a result, the inducements offered to mills to convert to electric driving will be economically very attractive.

In addition to the large contracts which The English Electric Company has completed for the Ribble Power station, and has in hand in connection with the interconnection schemes, the Company has a special interest owing to the location of their Dick, Kerr Works in the Preston Borough. Nor is that interest one of sentiment only, for, as some of our readers are probably aware, the electric supply for those works has recently been changed over to the Corporation mains and the site of the old works power plant converted to other uses.

In the course of this article the part played by this Company in the construction of the Ribble station will first be described, followed by some references to the plant in hand for the linking up schemes, and in conclusion some notes will be given on the progress made in transferring the Dick, Kerr Works supply to its new source.

Fig. 1 is a bird's-eye view, and Fig. 2 a block plan of the Corporation's new station which is built on the south bank of the river Ribble, about a mile and a half from the centre of the Borough. It has been constructed to the designs and specifications

* Constructed by The English Electric Company and described in the January, 1922, number of this Journal.

of Mr. J. A. Robertson, M.I.E.E., M.I.Mech.E., Consulting Engineer, assisted in the later stages by the Borough Electrical Engineer, Mr. J. F. Simpson, M.I.E.E., M.I.Mech.E., and his staff.

The contracts entrusted to The English Motor-Generators and over 32 Motors of various sizes for driving auxiliaries. A further contract was received for three 1,500 K.W. Rotary Converter equipments for the Crown Street substation, of which a view is shown in Fig. 8.

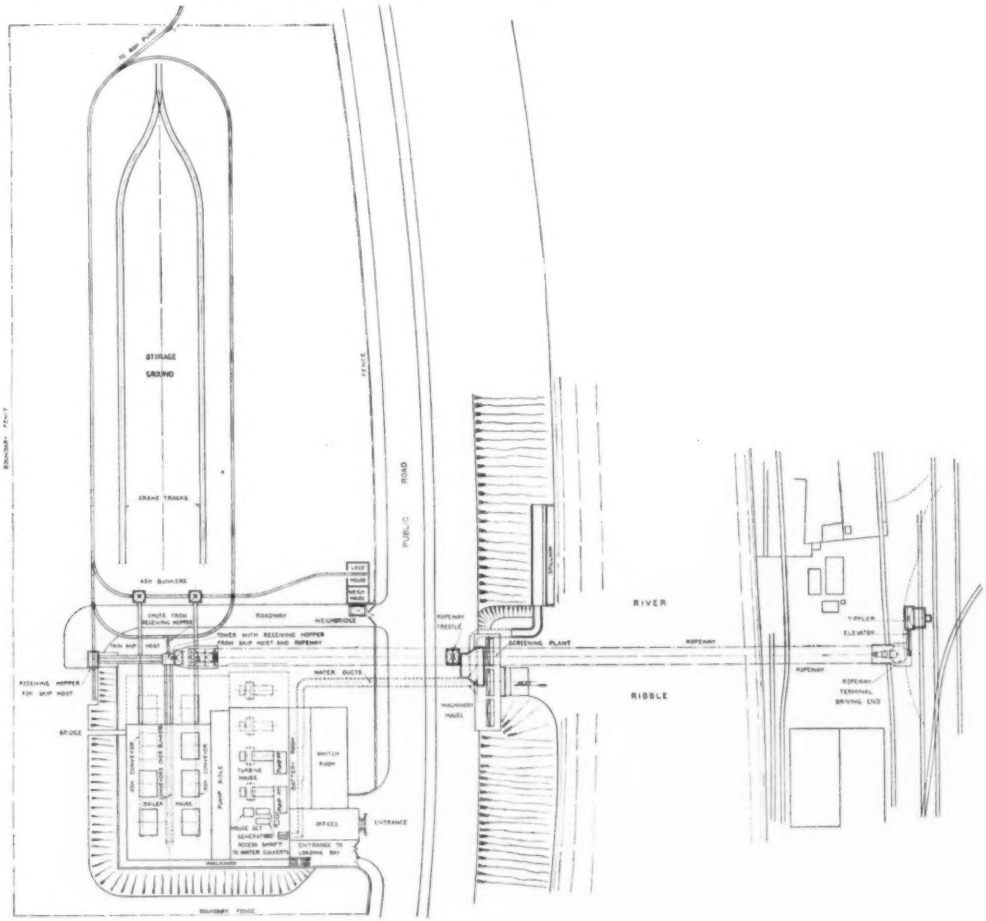


FIG. 2. BLOCK PLAN OF THE RIBBLE POWER STATION.

Electric Company included the erection of the Power Station structure and construction of the circulating water system, the supply and erection of two 12,500 K.W. Turbo-alternator sets with condensing plants, one 600 K.W. geared D.C. Turbo-generator House set, two 600 K.W.

The foundations are laid on a bed of red sandstone at a depth of 12 to 15 ft., down to which the site was excavated, and the buildings are of steel construction with brick filling, the whole being faced on the outside with Accrington bricks and inside with white glazed

bricks. The ample lighting provided by the large windows is a striking feature, and excellent arrangements have been made also for ventilation.

There are three parallel bays forming the turbine house in the centre, the boiler house on the south and the switchgear and offices on the river side. The turbine house is 77 ft. wide and is constructed for three main generating units of which two are already installed, and the third has now been ordered, but full provision has been made for extending the building to a final length of 180 feet when a fourth unit can be accommodated. Between the Turbine Room and the Boiler House is a pump aisle containing the pumps and auxiliary apparatus for the boiler feed system.

The Boiler House is 84 feet wide and 81 feet high with a total length when completed of 180 feet. Overhead Bunkers are provided, with a capacity of 900 tons of coal, and for the haulage of coal and ash trucks there is an " English Electric " battery locomotive, which is illustrated in Fig. 7.

In the third bay the first floor is occupied by the high-tension cubicle room while immediately below, space is reserved for earthing resistances, transformers, etc.

In planning the station the importance of convenient access to all parts was carefully considered, and the floors of the turbine and boiler houses are on the same level as the roadway which gives direct access into the turbine room through a transverse loading bay over which runs a 60-ton travelling crane.

The general lay-out of the Turbine Room can be gathered from Figs. 3 and 4 and Plates I. to III. Referring to Fig. 4, the two 12,500 K.W. Turbo-alternator sets are at the distant end, and in the foreground are the 600 K.W. House Sets, one turbine-driven and two driven by induction motors.

On the right can be seen, in the basement, three of the five circulating pump motors, while

FIG. 3. TURBINE ROOM SHOWING TWO 12,500 K.W. SETS IN FOREGROUND.

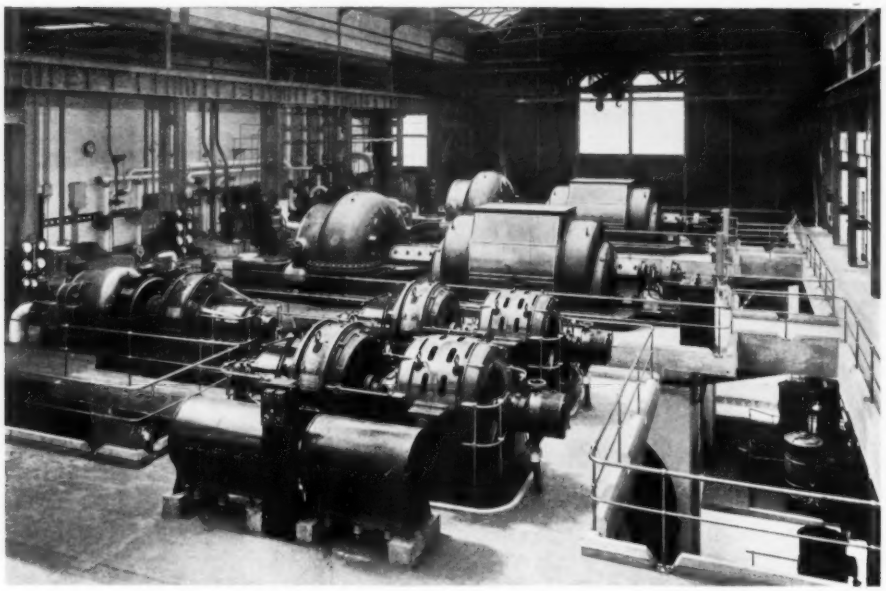


FIG. 4. TURBINE ROOM SHOWING THE THREE 600 K.W. HOUSE SETS IN FOREGROUND.

the aisle on the extreme left, adjoining the boiler house, contains the steam and motor-driven feed pumps. The relative levels will be made clear by reference to Plate I., which shows a cross section of the whole station.

The planning of the circulating water supply presented certain difficulties owing to the variation in the water levels in the river by some 26 feet between dry weather flow and maximum flood level. It was considered that the circulating pumps should be below low water level at all conditions of working, in order to eliminate any possible risk of the condensers losing their water and so causing the sets to shut down, and it was finally decided to have the turbine and boiler house floors at 28·0 O.D., the turbine-house basement at 8·0 O.D. and the pump pits at −11·0 O.D. The construction of these pits was one of considerable difficulty and was carried out without a dam. The discharge culvert is arranged immediately above the suction culvert, and each is 7 ft. 6 in. high by 6 ft. wide stepping down to 4 ft. wide for the second turbine set.

Each main turbine is of the simple impulse type designed to run at 3,000 R.P.M. with steam at 300 lbs. per square inch and a temperature of 700° F. There are seven stages and the discs, which vary in diameter from 53 in. to 63 in., carry a single row of impulse blades. The high-pressure diaphragm and all parts which are in contact with high-temperature steam are of steel. The centrifugal governor is enclosed in the steam-end bearing pedestal, and its motion is transmitted to the governor lever by means of a differential piston controlled by an oil leak-off. There is a single oil pump for the bearings and the servo-motor, the latter operating at the full pump pressure of 60 lbs. per square inch, whereas the bearings receive their supply through a reducing valve which is adjusted to give 15 lbs. per square inch. An auxiliary oil pump is fitted of the steam-turbine driven centrifugal type.

The alternators have a maximum continuous rating of 13,900 K.V.A. at 0·9 Power Factor and generate a three-phase supply at 50 cycles per second, 6,600 volts between phases.

The stator frame is a strongly ribbed casting with flanged openings at the top and bottom through either of which the heated air can be expelled. The outside of the frame is covered with planished steel sheet, and this construction gives a frame which is relatively light but of great rigidity. In the interior periphery of the frame dovetail grooves are machined to receive the stator laminations; no bolted-on keys are used. The laminations are insulated from the frame by moulded insulation of a specially tough nature.

The ends of the stator frame are completely enclosed by cast-iron shields shaped at the bottom to form openings through which clean cool air is drawn into the machine from below by means of a fan fitted at each end of the rotor. To prevent oil from the bearings being drawn along the shaft, a sealing chamber is provided and connected to the exhaust side of the circulating air system. After passing through the fans the air flows through the stator end windings and then in parallel paths through the air gap and axial ventilating holes in the stator laminations. The outlet areas and radial ventilating ducts are so proportioned and arranged that the central part of the machine receives a greater amount of air than the ends. The heated air is discharged from the bottom of the machine through a Heenan & Froude air cooler after which the flow divides, and half passes to each of the inlets of the alternator. The air circulates at the rate of approximately 40,000 cubic feet per minute.

The rotor shaft and body are formed out of one solid forging of steel having an ultimate tensile strength of 40 tons per square inch, while the end bells which hold in place the overhanging ends of the windings are of a special alloy steel which has an ultimate strength of 58/62 tons per square inch. Mica insulation is used throughout the machines, and special attention has been given in the design to providing ample mechanical support for the end windings of both the rotor and stator so as to prevent any movement under the most severe conditions of load or speed which may arise.

Each turbo set exhausts into an " English Electric " Surface Condenser of 17,000 square feet, which is supplied with 13,000 gallons of cooling water per minute at a temperature of 53° F.

As will be seen from reference to Plate I. and Fig. 6 the circulating water pumps are of the vertical spindle type situated on a level with the suction culvert and with their motors on the condenser floor level.

There are two pumps to each condenser and the direct-current motors are standard " English Electric " C.B. machines of the vertical-spindle type. The Hick-Hargreaves air ejectors of which there are three to each set, are mounted on the Turbine Room level near the driver's station.

In Fig. 5 can be seen the condensers and their extraction pumps, each comprising a two-stage horizontal Drysdale pump driven by an " English Electric " 220-volt D.C. motor. There are two 100 per cent. duty pumps for each set and each has a maximum duty of 150,000 lbs. per hour; they discharge into a closed-feed system.

For the supply of the auxiliary machinery throughout the station there are three 600 K.W., 220-volt, direct-current units, all of which can be seen in Fig. 4. One of these is driven through gearing by a 6,000 R.P.M. six-stage " English Electric " Steam Turbine, and the other two are direct-coupled to 6,600-volt " English Electric " Induction Motors. The steam set exhausts into a 1,200 square feet Surface Condenser with a motor-driven circulating pump similar to those used for the main sets, but, in this case, with a capacity of 900 gallons per minute.

The closed feed system is shown diagramatically in Plate IV.

In the present case it was decided to feed heat by bleeding from a low-pressure stage of the main turbines, and supplement it with a moderate amount of exhaust steam heating

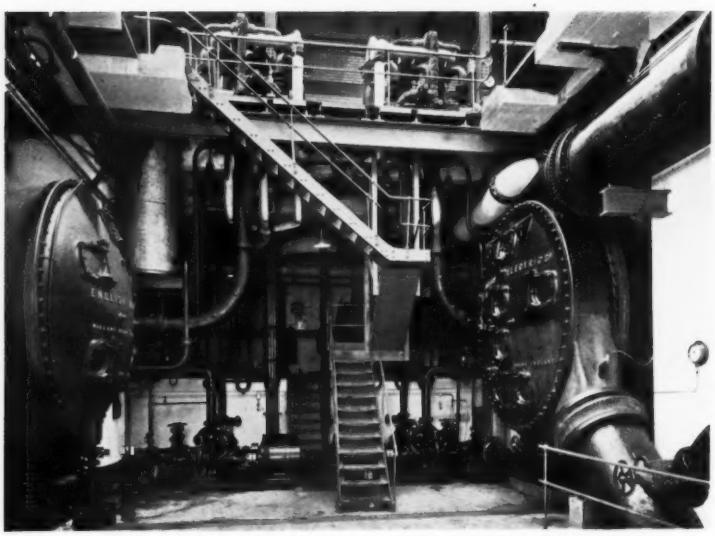


FIG. 5. CONDENSERS AND EXTRACTION PUMPS FOR THE MAIN SETS.

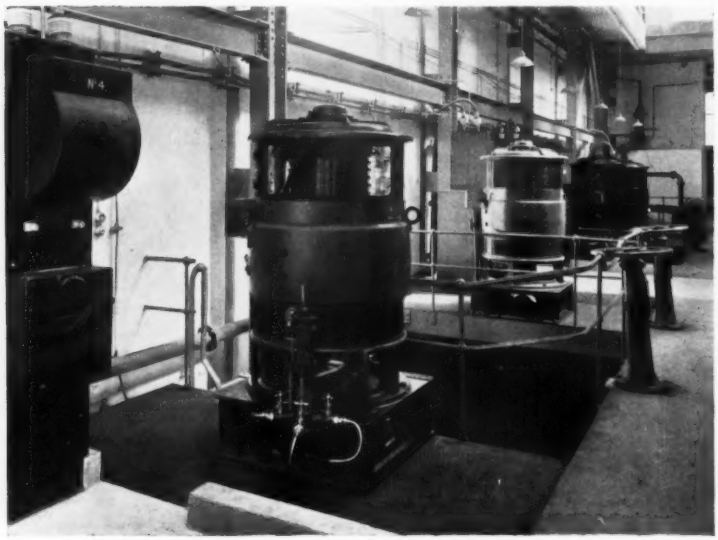


FIG. 6. CIRCULATING PUMP MOTORS ON CONDENSER FLOOR LEVEL.

from the boiler feed pumps; this method gives a fairly uniform feed temperature at all loads on the main sets.

Referring to Plate IV., and following the description from either turbine, the condensate enters the condensate pump—one only being in use—through the valve V. 10 and is discharged through the valve V.6 into the pipe leading to the vacuum heater. Prior to the heater, part of the condensate passes up the pipe to the air ejectors, where it condenses the steam of the primary jet and cools the air in a small jet condenser; it is discharged back into the condensate pump suction—not to the condenser—through a U-tube which balances the difference in pressure between the air ejector condenser and the main condenser. Between the pipe to the air ejector and the vacuum heater is a Kent's recording Venturi meter. The vacuum heater has a surface of 330 square feet, and is supplied by steam bled from the last stage of the main turbine at a pressure of 2.5 lbs. square inch absolute, at full load, increasing the feed temperature by about 44° F. After passing through the vacuum heater the condensate enters the atmospheric heater of 113 square feet, where the feed is raised by about 33° F. from the heat in the exhaust steam of the boiler feed pumps and the secondary jets of the air ejector. The drips from the vacuum heater are returned to the condenser by way of a U-pipe, and from the atmospheric heater through a water seal trap.

After leaving the second heater the feed water enters the feed pump suction through the valve V.14. Attached to the suction main are two 5-inch rising pipes, terminating in surge tanks. Situated above the surge tanks is a make-up water tank of 3,600 gallons capacity which is supplied from the town mains, the water being of excellent quality for boiler feeding. In the surge tanks are float gears controlling valves V.31 in the pipe leading from the make-up water tank to the main condensers. The make-up water is, therefore, admitted to the system as and when required, and passes through the main condensers, where it is deaerated before passing to the boilers.

A pair of test tanks is placed above the surge tanks for the purpose of checking the turbine consumptions.

Reference to the Closed-Feed diagram (Plate IV.) shows that the feed heating takes place in either two or three stages. The first is to absorb the heat in the steam from the primary jets of the air ejectors. To carry this out a proportion of the condensate from the extraction pump is shunted through a small jet condenser, and is returned, together with the primary steam condensate, to the suction of the condensate pump. The amount of heat received is not much, and is not enough to upset the working of the con-

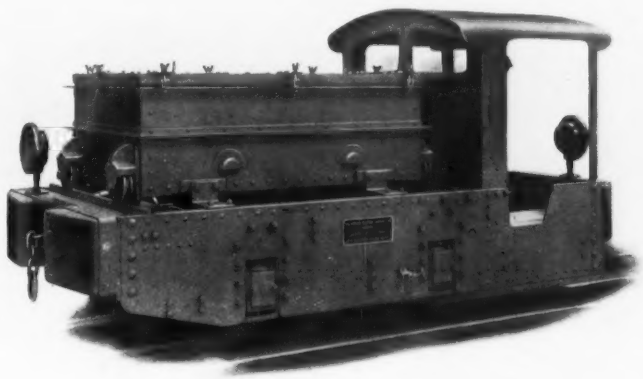


Fig. 7. Battery Locomotive for haulage of Coal and Ash Trucks.

densate extraction pump. The coldest feed is used here, because the steam is low in temperature. The feed is then passed through the bled steam heater, which is supplied with steam taken from the front of the last wheel in the turbine, in which it has already given up the greater part of its available heat.

After passing the bled heater the feed enters the atmospheric heater, where the boiler feed pump exhaust steam and the steam from the secondary jets of the air ejectors further heat it.

Since the exhaust steam does not vary in quantity with the load—in fact, is very nearly constant—the temperature rise in this heater, unlike that in the bled heater, is greater at light loads and becomes less as the plant is loaded up. The combination of the two, therefore, tends to even out the final feed temperature.

In order to provide an economical means of interchanging power between the supply systems of the Preston and Blackburn Corporations, it was decided to instal a high-voltage link, and for this purpose 33,000-volt underground cables have been laid. At each end of the line the generator voltage will be stepped up from 6,600 volts to 33,000 volts by means of transformers which are to be installed in outdoor substations for which complete equipment is being supplied by this Company. The two substations will be exactly similar in arrangement, and each will contain a bank of three single-phase transformers with a capacity of 8,700 K.V.A. A fourth single-phase unit will be installed as a spare, and the overhead switching gear will be arranged in such a way that by simple manipulation of isolating switches the spare unit may be connected in place of any unit in the bank.

From technical considerations the shell type of construction has been used. The tanks are of the tubular type and circular in shape, and

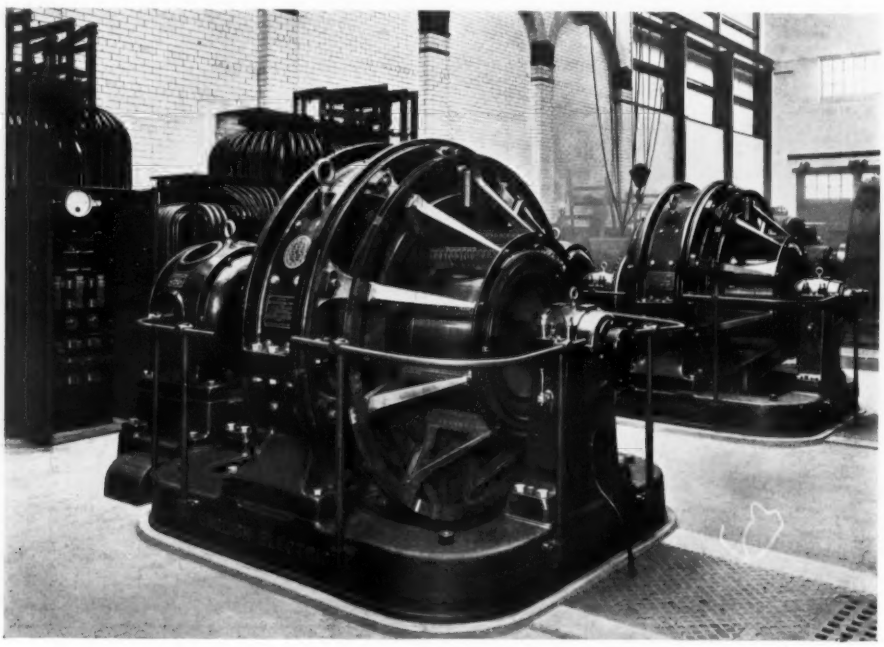


FIG. 8. 1,500 K.W. ROTARY CONVERTER EQUIPMENTS IN CROWN ST. SUBSTATION.

are equipped with expansion vessels. The outlet bushings are made of porcelain, located in pockets at the sides of the tank and designed to be weatherproof.

In order to control the flow of power in either direction, a three-phase Induction Regulator will be installed on the 6,600-volt side of each bank of transformers. These regulators are motor controlled and of the oil-immersed type with tubular tanks of circular shape, and are amongst the largest that have been manufactured in this country up to the present time.

As already mentioned, an interconnection is being effected also between the Preston system and that of the Lancashire Electric Power Company, and for this purpose two three-phase transformers each of 2,500 K.V.A. are in course of construction. These will have a voltage ratio of 11,000/6,000, and as they will be installed in existing substation premises they will be of the indoor type.

Although the power plant of the Dick, Kerr Works had been completely modernised since the War, so that it was possible to generate very economically, the development of the Corporation supply undertaking, which culminated in the Ribble station, led to an investigation of the advantages to be gained by transferring the works load to the public mains. It was decided that still greater economy could be effected by adopting this course, and the result of more detailed consideration was the adoption of a plan for a joint substation which would supply the works and also be a Corporation distributing centre for the Docks and Marsh Lane areas. This substation has been installed in the old Works power house from which the boilers, generating sets, switchboards, etc., have been removed for disposal. Power is delivered to the new substation by two 6,600-volt feeders which terminate in the cellular type switchboard shown in Fig. 9. This board contains distribution circuits for the Corporation plant and for a separate Works switchboard of similar type.

The Works plant consists of:—

1-1000 K.W. Rotary Converter equipment.
1-1400 K.W. Motor-Generator for special testing.

and the Corporation plant of 2-500 K.W. Rotary Converter equipments with space for a third equipment.

Each Rotary Converter is provided with its associated transformer and starting apparatus, and there are separate switchboards of the panel type for controlling the direct-current output. Fig. 11 is a view of the Corporation plant consisting of standard "English Electric" tap-starting converters each with its starting pillar, and in the background is seen the switchboard for the D.C. distribution circuits.

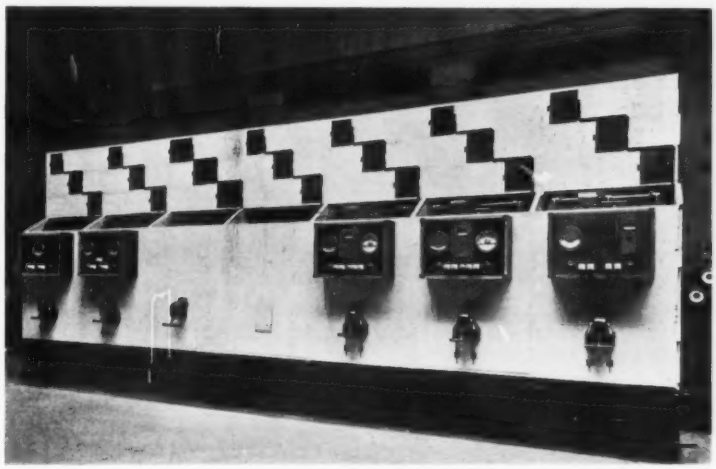


FIG. 9. E.H.T. SWITCHBOARD IN THE JOINT CORPORATION-ENGLISH ELECTRIC SUBSTATION.

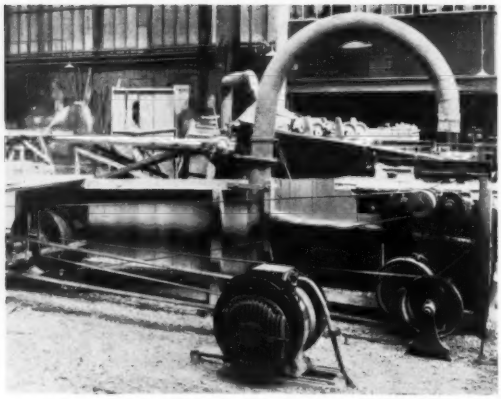


FIG. 10. A TYPICAL DRIVE BY TOTALLY-ENCLOSED INDUCTION MOTOR.

The switching and metering arrangements are such that an interchange of supply can be effected if necessary between the two sides of the joint station.

Before the change-over the Machine Works were driven by D.C. 500-volt motors and the Car Works by 240-volt machines; the opportunity was taken to convert to A.C. motors all those drives in the Machine Works where a reasonably steady load was assured, and to change over completely to A.C. in the Car Works where there is a large number of individual drives. For machine drives squirrel-cage 420-volt motors have been installed consisting of some 30 motors in the Machine Works and 54 motors in the Car Works with an aggregate rating of about 1,200 H.P. A number of D.C. drives have been retained in the Machine Works where a direct-current supply is required also for the testing of traction equipments, etc.

The substation furnishes the supply of power required by the adjoining factory of Siemens & English Electric Lamp Company.

As regards the economy of the new arrangements it is estimated that there will be a complete return of the capital expenditure in about six years, and in addition an increased manufacturing area has been obtained by the liberation of the space occupied by the boilers and coal bunkers.

The conversion of the power house from a generating station to a substation, and the changing of the shops from D.C. to A.C. motors was effected without in any way disturbing the operation of the factory, and in order to accomplish this every move was carefully studied beforehand, and no change was made until the whole programme had been planned out. In changing the shop drives it was possible in most cases to erect the new A.C. motor on a different site to the D.C. machine so that the transfer was effected finally during the mid-day interval. Where this simple plan could not be followed the work was done at a week-end.

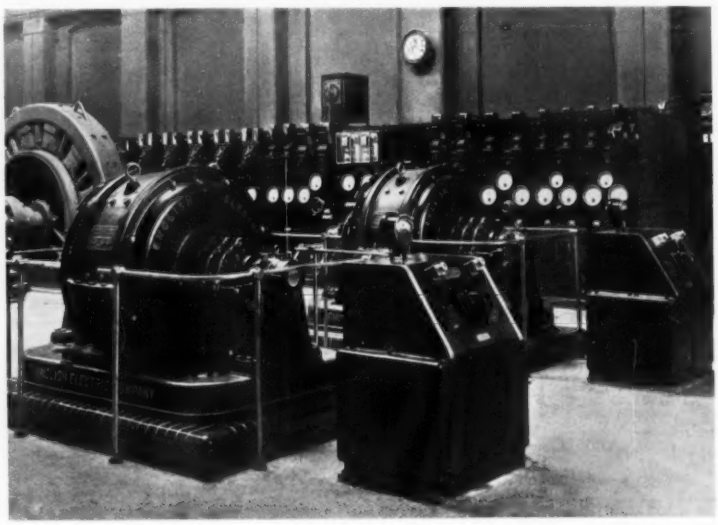
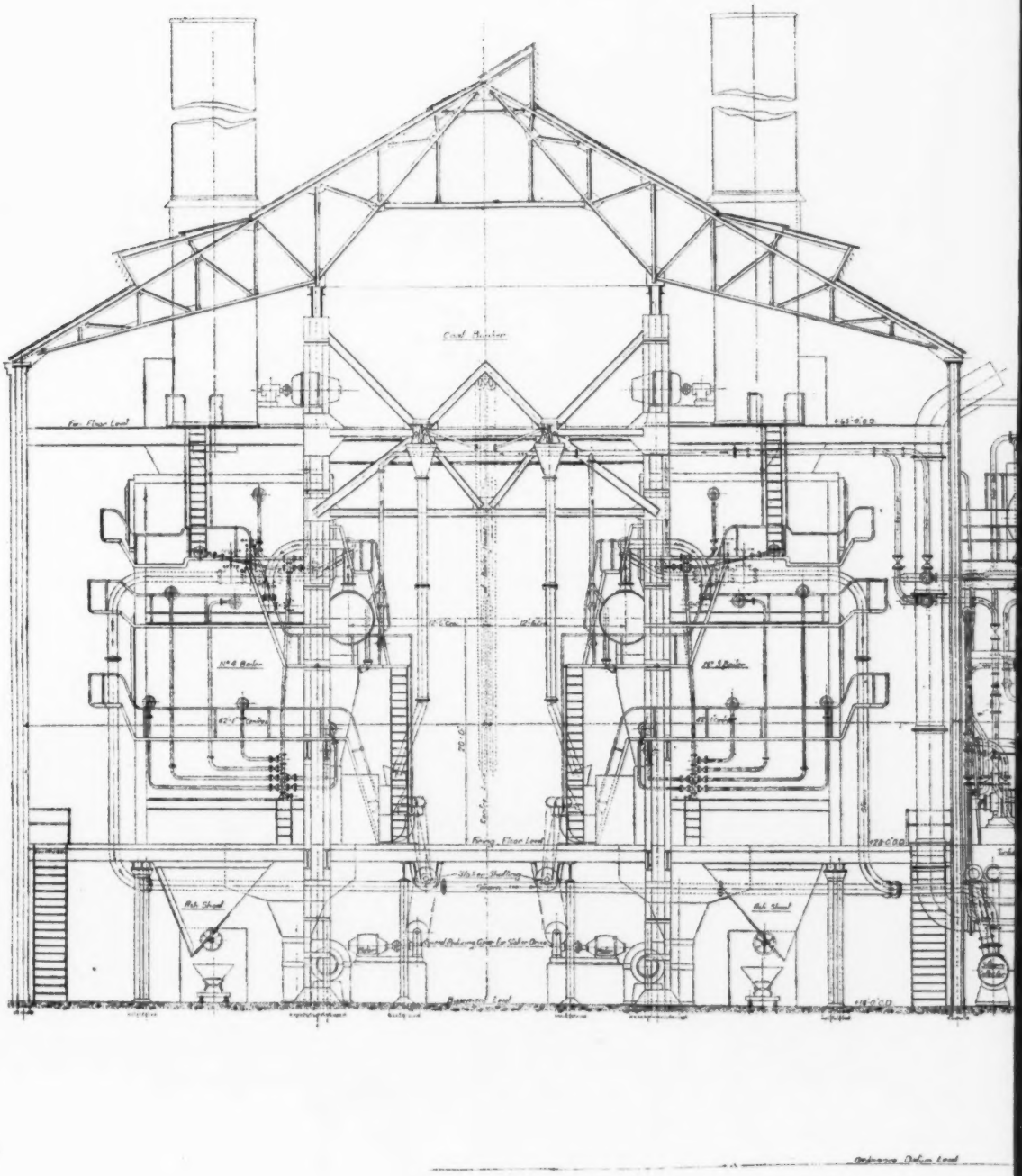
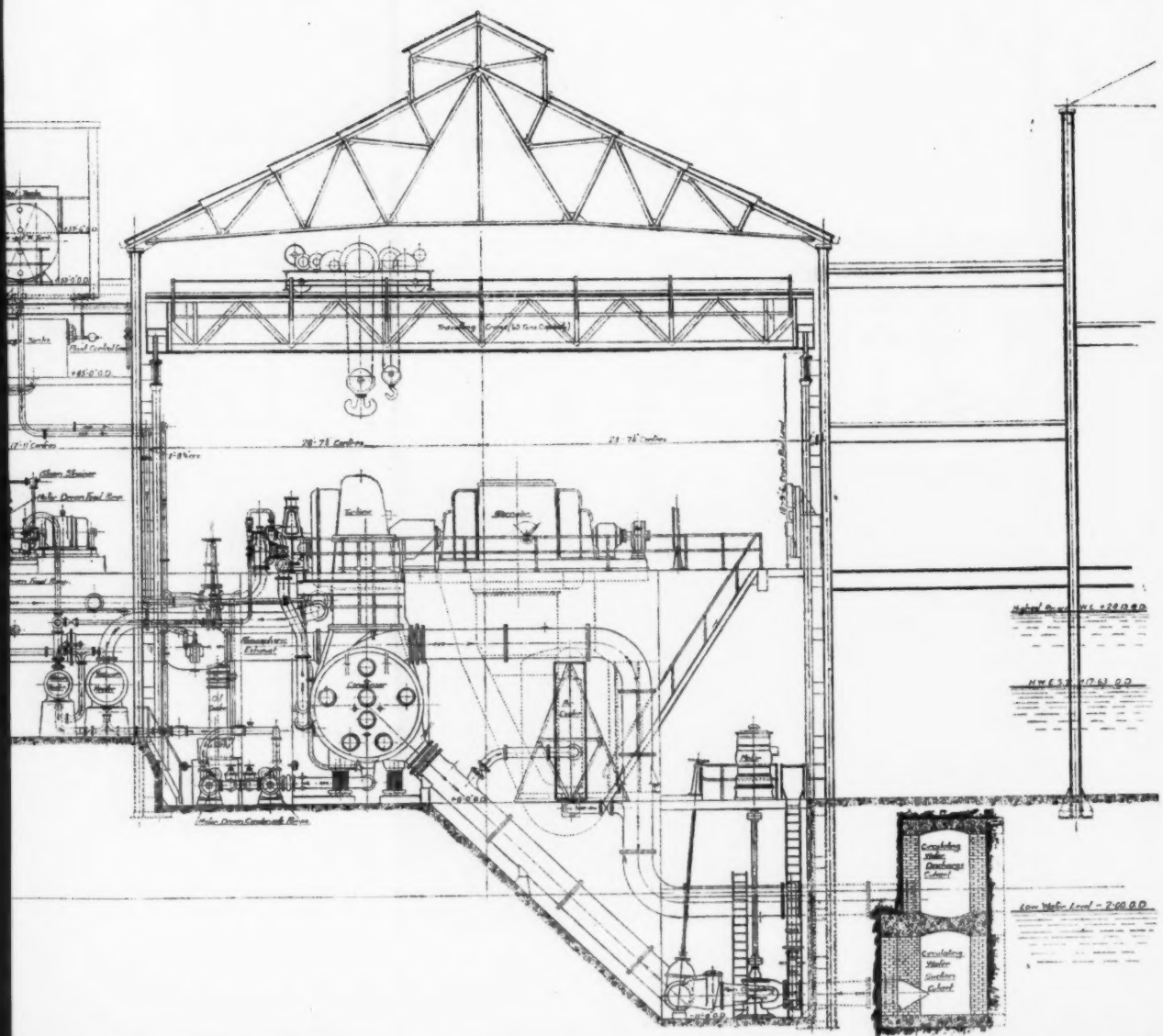


FIG. 11. 500 K.W. CORPORATION ROTARY CONVERTERS AND D.C. SWITCHBOARD.


Coal Hopper
for Floor Level
No 6 Boiler
No 5 Boiler
Firing Floor Level
Ash Shoot
Ash Shoot
Ordnance Datum Level



ECTION OF RIBBLE POWER STATION.

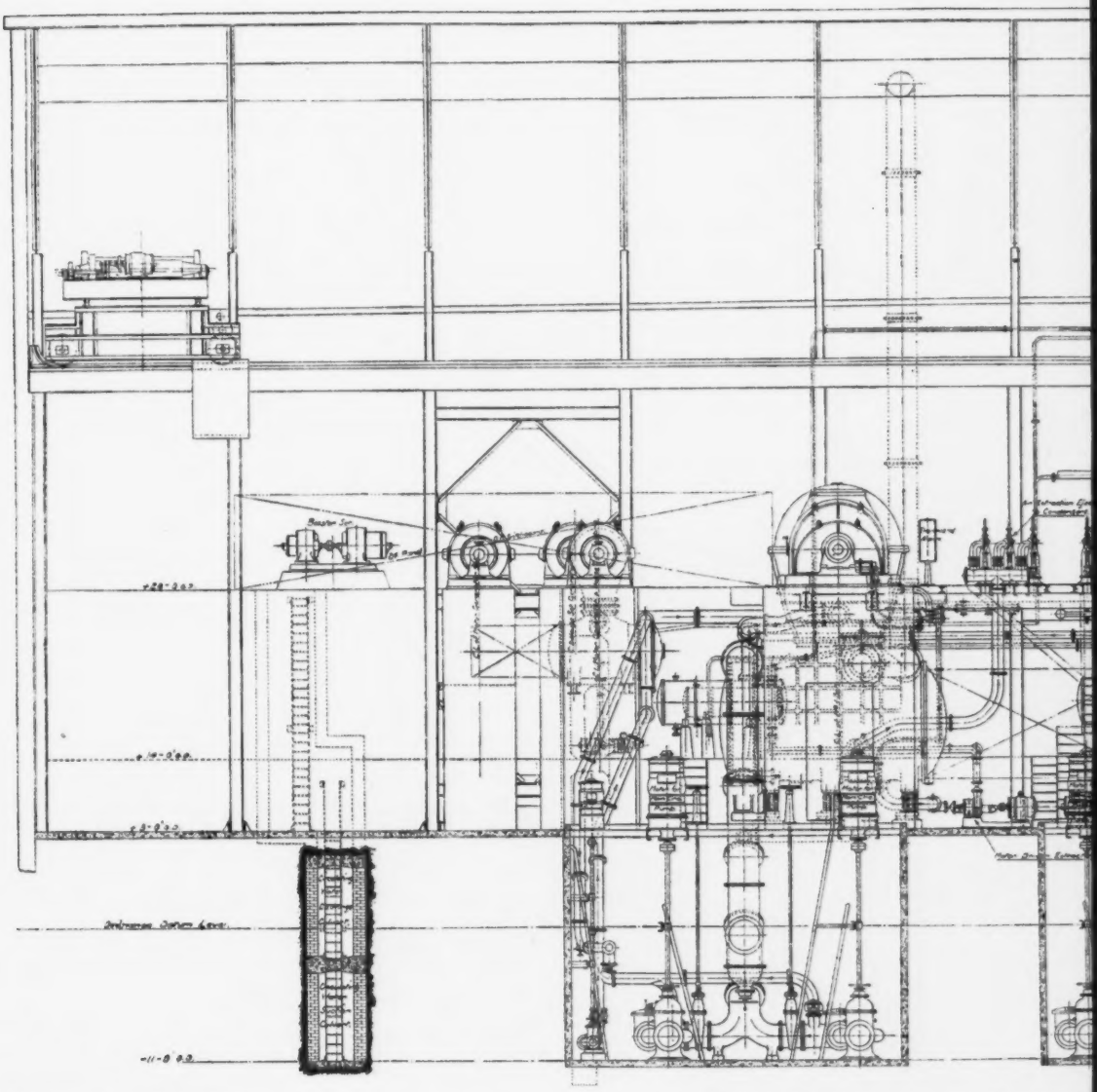
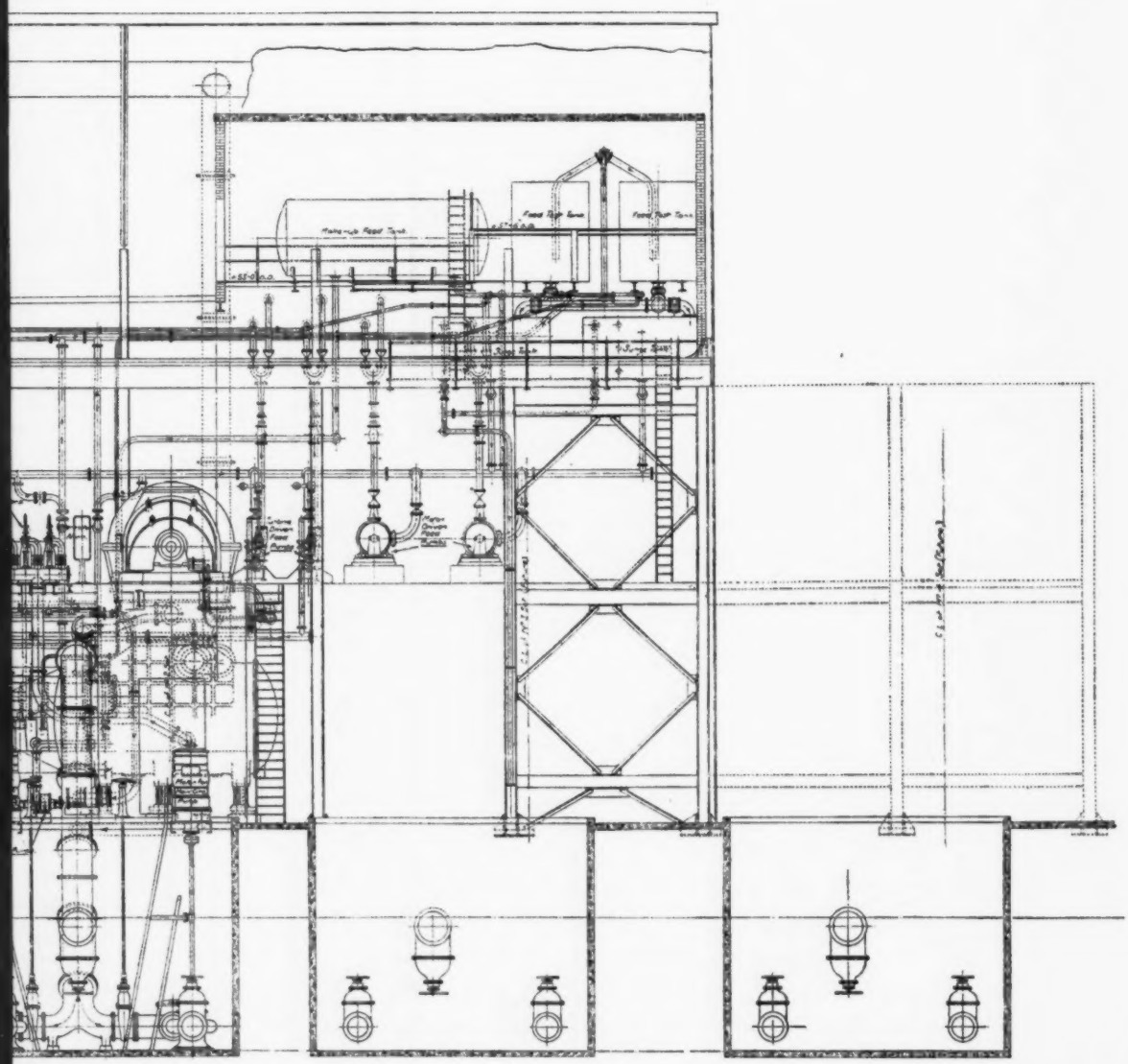


PLATE II.—LONGITUDINAL SECTION O



Turbine Room, Ribble Power Station.

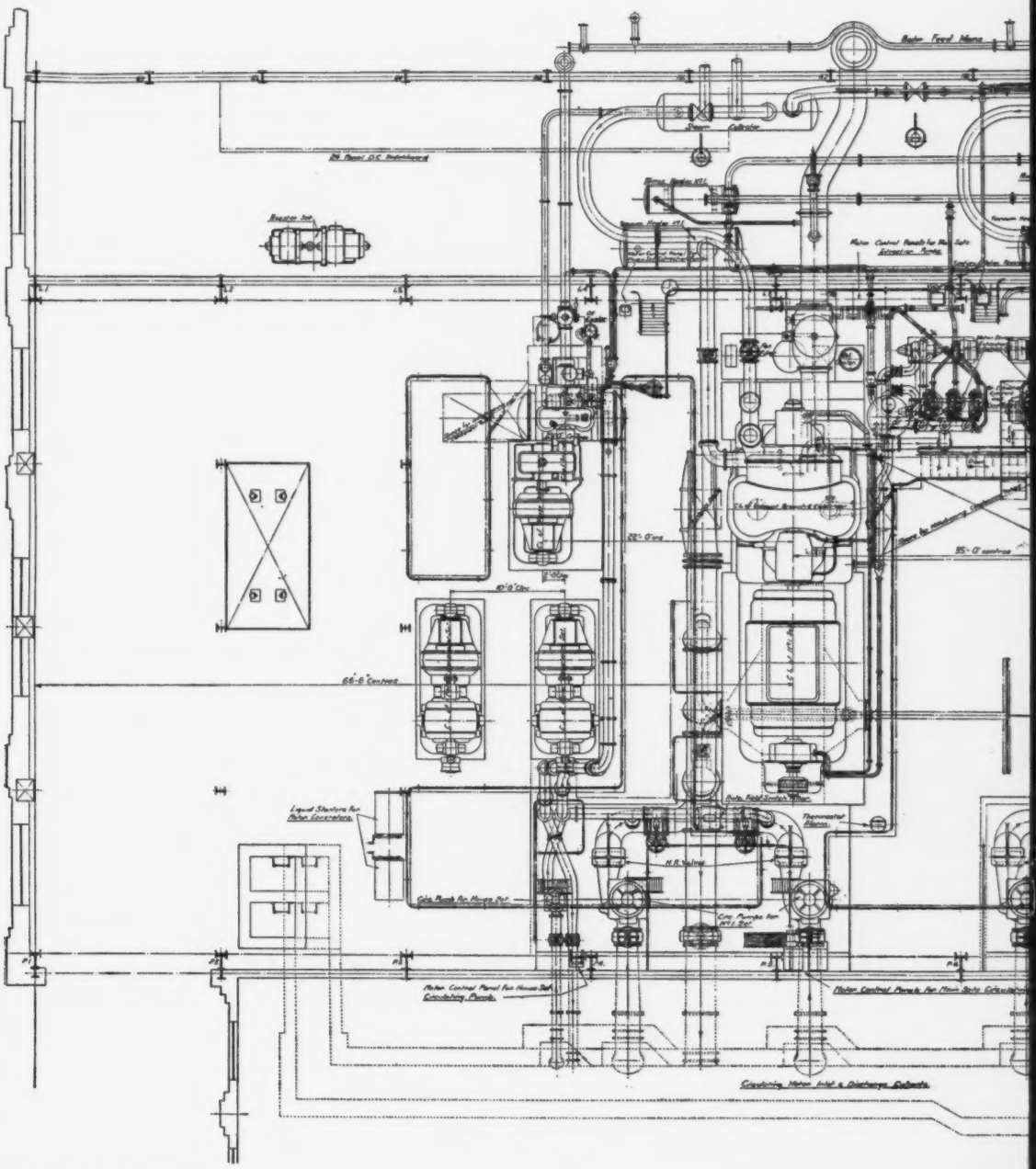
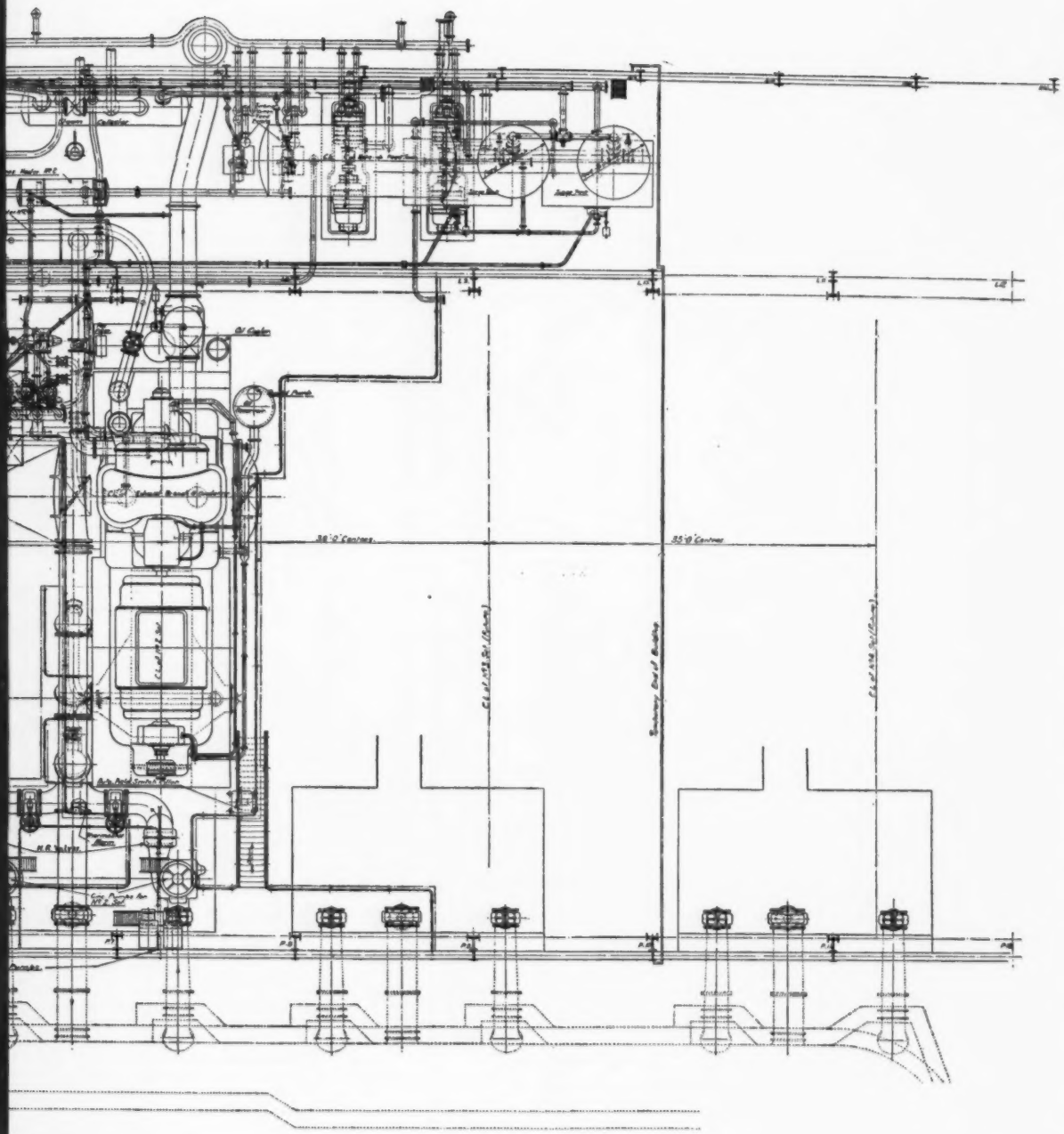

66'-0" Centres
Liquid Starters for Motor Generators
Motor Control Panel for House Set Circulating Pumps
Circulating Motor Inlet & Discharge Culverts

PLATE III.—PLAN OF TURBI



E Room, Ribble Power Station.

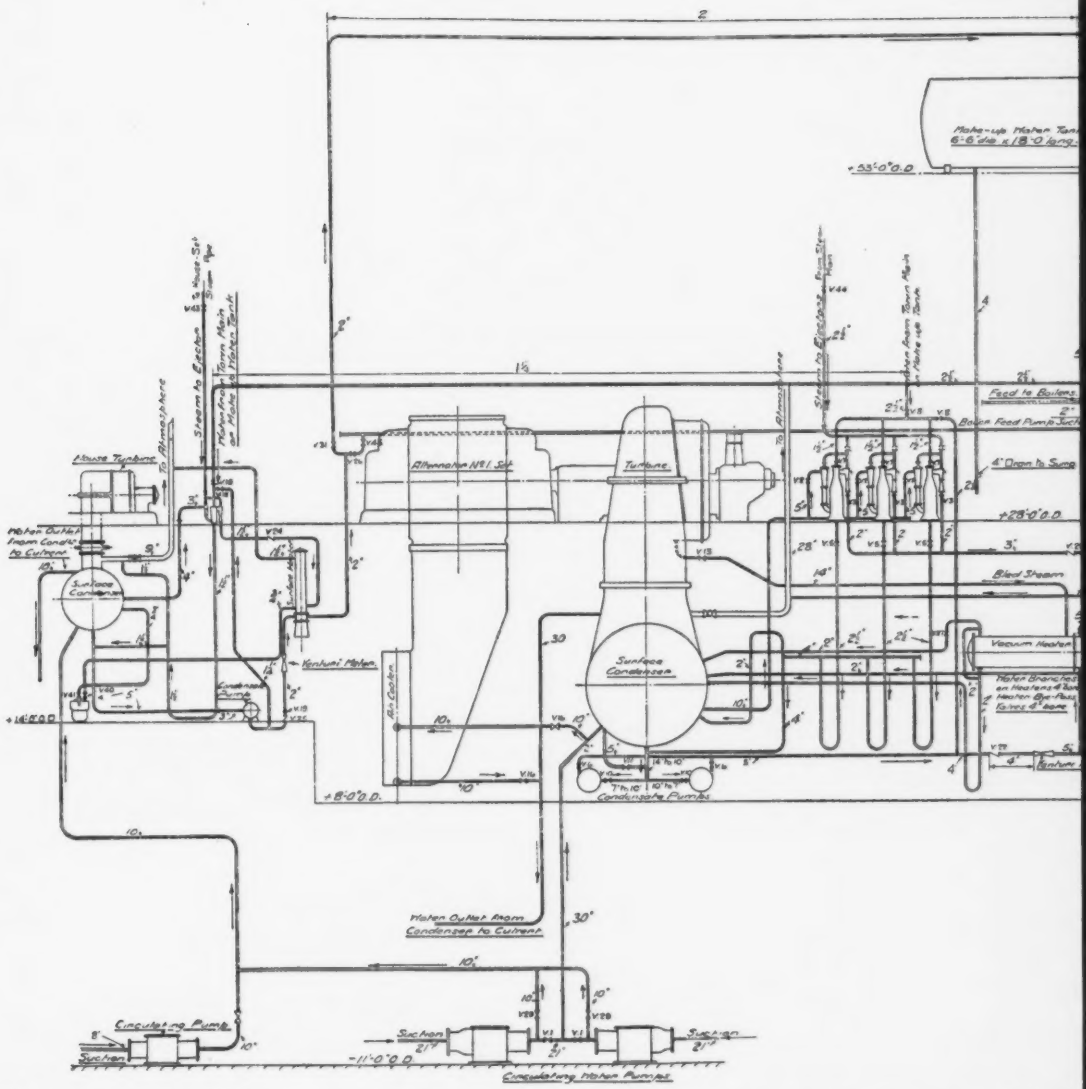
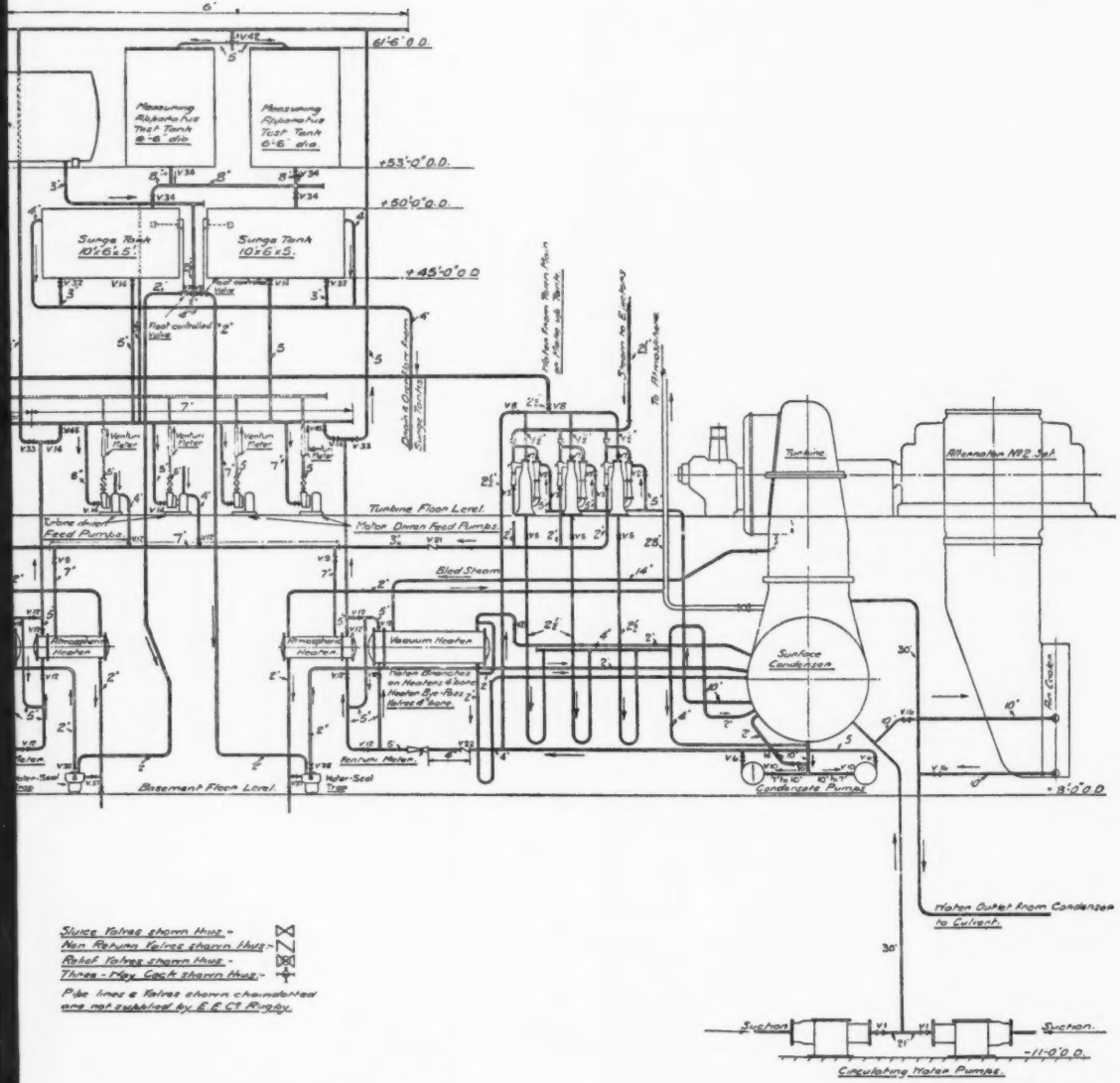


PLATE IV.—DIAGRAM OF CLOSED



Sluice Valves shown thus -
Non Return Valves shown thus -
Relief Valves shown thus -
Three - Way Cocks shown thus -

Pipe lines & Valves shown chain dotted are not supplied by E.E.Co. Rugby.

FEED SYSTEM, RIBBLE POWER STATION.

"English Electric" Equipments on the Noord Zuid Hollandsche Tramweg.

The Noord Zuid Hollandsche Tramweg operates in Holland over a considerable area from Haarlem in the North to S'Gravenhage and Scheveningen in the South, and also provides a means of communication between Amsterdam and Haarlem and Zandvoort in the Eastern and Western directions. The total length of line of the electrified system is now about 110 kilometres, and the various tracks are shown in Fig. 1. The greater portion of the track is of standard 4 ft. 8½ in. gauge, whilst the remainder is of metre gauge.

For the year ending December 31st, 1924, the total number of passengers carried irrespective of season ticket holders, was 20,100,000, the car miles run being 5,100,000. The total current taken for the system including that necessary for the lighting and for the workshops was 9,243,000 KW-hours.

FIG. 1. MAP OF SYSTEM.

The whole system is built in such a way that eventually it may be operated at 1,500 volts D.C., but at present the standard gauge track is electrified at 1,100/1,200 volts with the metre gauge track at 600 volts. These voltages may be raised in course of time, as stated, to 1,500 volts, and the maximum pressure on which the various equipments will then be called to operate will be 1,650 volts; the gear which the Company has recently supplied has been designed to operate on this voltage without alteration.

The control apparatus is operated at 120 volts D.C., the control current being supplied by a motor-generator.

The overhead construction is of single catenary type, the catenary wires being carried by concrete poles placed between the two tracks in the interurban sections, whilst in the towns, the trolley wire is carried from steel poles placed on both sides of the track. An example of the special work at a curve is shown in Fig. 3.

Trains are made up of one motor car, Type 400, and 1 to 3 trailer cars, the number of trailer cars being determined by the state of the traffic. The motor cars weigh 35 tons under service conditions, including passengers, and the trailers each weigh 25 tons. The normal standard train consists of one motor car and two trailers and has a service weight of 85 tons.

As will be seen from the illustrations, these cars are of the centre entrance type with separate entrance and exit doors to facilitate the handling of rush-hour traffic. The two pantographs provided are raised and lowered manually through bevel gearing and operating rods from the driver's compartments. The pantographs are generally of standard construction, but have been modified to meet the special conditions which have to be met in

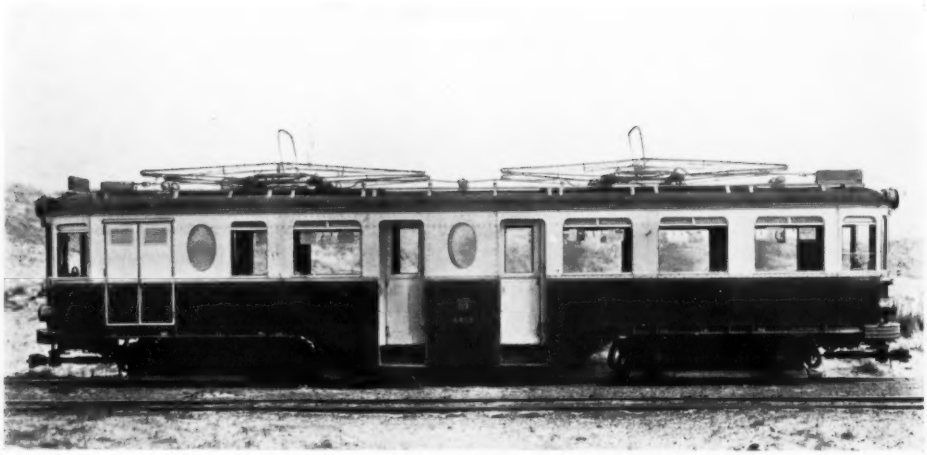


FIG. 2. MOTOR COACH WITH PANTOGRAPHS LOWERED.

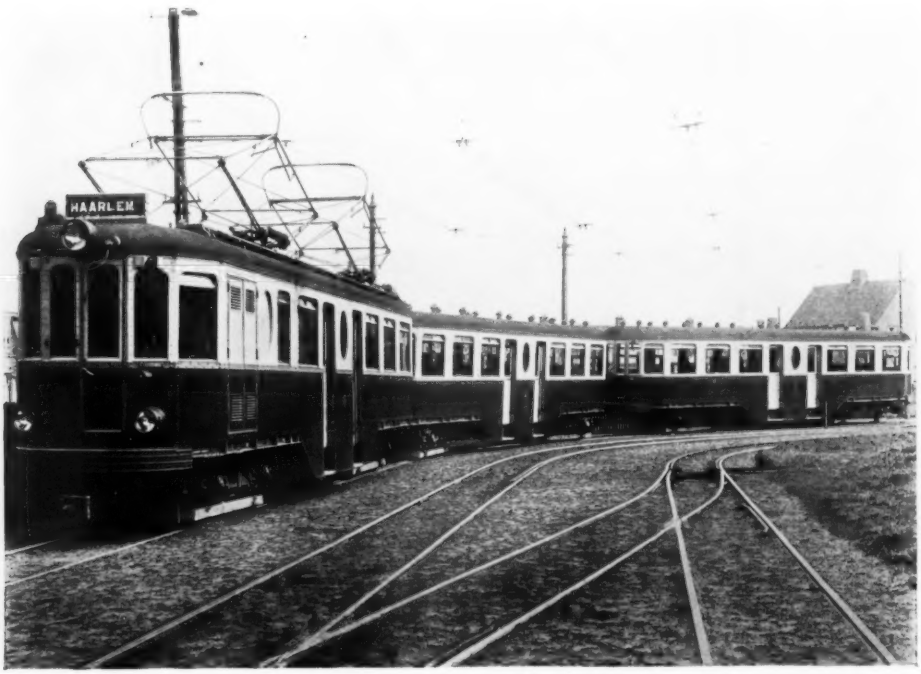


FIG. 3. THREE-COACH TRAIN AND OVERHEAD CONSTRUCTION AT A CURVE.

operation. Owing to a number of low bridges where the height of the trolley wire changes very rapidly, spring bows have been fitted to the pantographs (as will be seen in Fig. 3) in place of the more usual pan. This fitment has proved very satisfactory and the pantographs are capable of collecting heavy currents at all speeds without excessive sparking. The use of ball bearings and a special arrangement of springs serve to maintain the pressure on the trolley wire within narrow limits over the whole working range of about 2·75 metres.

A driving compartment is provided at each end of the motor cars, fitted with a master controller with dead man's handle and the usual control switches.

The high-tension compartment is accommodated at one end of the car and Fig. 4 shows the arrangement of the gear inside this compartment on a standard gauge coach. As will be seen, the control apparatus is mounted on a framework and the layout has been designed to afford complete accessibility to the various moving portions of the equipment. It will be noted how well the various items lend themselves to such an arrangement.

The photograph shows (A) the camshaft with driving motor and position regulator, (B) the cam-operated line breakers, (C) reverser, (D) motor cut-out switch, (E) control resistances, (F) field shunt contactors, (G) cam motor relay, and (H) main starting resistances. More detailed information regarding these items is given later.

The motor-generator and air compressor are not shown, but they are mounted on the floor of the coach below the control gear framework. The main circuit-breaker is also mounted in the H.T. compartment.

It will be seen that the main starting resistances are mounted above the remainder of the equipment and adequate ventilation is provided to ensure that the heated air is dispelled as rapidly as possible.

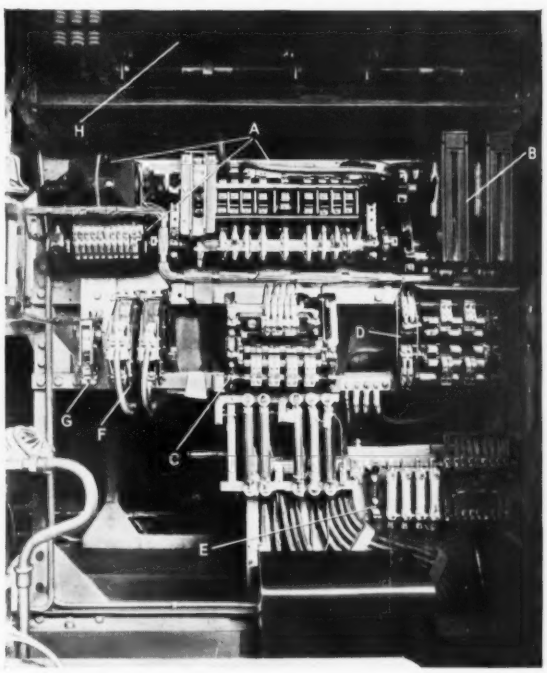


FIG. 4. HIGH-TENSION COMPARTMENT ON STANDARD GAUGE COACH.

The control gear shown is of the standard " English Electric " camshaft type. The camshaft is driven by a small camshaft motor and carries 11 cams which open and close the resistance contactors in definite sequence giving five series notches and four parallel notches, and with the two solenoid-operated contactors one field shunt notch. By the use of cams a definite mechanical control over the sequence of operation is obtained, and it is not necessary to fit electrical interlocks to the resistance contactors.

These contactors with the exception of the transition contactor do not break current, so that it has been found possible to dispense with blow-outs. The transition contactor, however, which has to deal with the comparatively small current during transition from series to parallel has been fitted with a

blow-out. As can be seen from Fig. 4 the omission of blow-outs and electrical interlocks makes for a very compact arrangement, and, of course, considerably reduces maintenance.

The main circuit is broken on a pair of cam-operated line breakers. The cam operation ensures a constant contact pressure independent of the line voltage, and by means of a toggle and holding coil an interlock is provided so that the line breakers cannot be closed by the cams until the control circuit is correctly energised. This arrangement also ensures that when the holding coil is de-energised by shutting off the master controller the line breakers are opened independently of the position of the camshaft.

Overloads are dealt with by means of a main circuit-breaker which is fitted with a powerful magnetic blow-out and an automatic overload feature accurately calibrated, and is arranged for remote setting and tripping from the driving positions.

The reverser is of the standard drum type, and is thrown directly to either the ahead or reverse position by means of heavy solenoid plungers. Motor cut-out switches are provided to isolate any motor if this should be found necessary in service.

The actual method of operation is as follows:

The pantograph is raised by an operating handle in the driver's cab, and the motor-generator set is started by closing its main switch. The main control switch in the driver's cab is then closed and the reverser handle of the master controller is thrown into the running position (either forward or reverse). It is now possible to energise all power and control circuits. The main circuit-breaker is set electrically and this now closes the main power circuit to the cam-operated line breakers. As the reverser handle on the master controller has been thrown already to the position for the correct direction of motion, the main power handle is moved to first notch, and we have the following sequence of operation:—

(a) The reverser is set.
(b) The control circuit of the line breakers is energised and by means of auxiliary contacts the camshaft motor is set for rotating in the forward position.
(c) The camshaft runs to the first notch and the line breakers are closed.

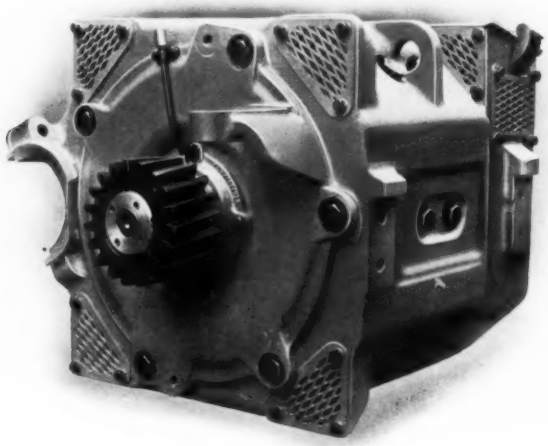


FIG. 5. D.K. 91A, 125 H.P. MOTOR FOR STANDARD GAUGE COACHES.

As the master controller is advanced notch by notch the camshaft moves to the corresponding notch under the control of the position regulator which rotates with the camshaft.

The principle of operation is briefly that the movement of the master controller energises the cam motor until the camshaft reaches the correct notch. At this point the cam motor is short-circuited under full field, giving a dead-beat check to the movement of the camshaft. This ensures the camshaft stopping at the predetermined notch.

Upon the master controller being moved in the direction of the " off " position, the line breakers open, thereby reversing the camshaft motor and the camshaft is returned to the " off " position.

In the particular case under consideration, the control equipments are not arranged for multiple-unit operation, and are normally operated as single motor cars with trailer cars under manual control. Provision has been made, however, for automatic control, so that if this should be desired in the future the necessary changeover can be made by the addition of a current limit or accelerating relay, without further modifications to the existing equipment.

The main motors which were supplied by this Company are of three types. The DK. 91A motor of 125 horse power at the one-hour rating on 550 volts, insulated for 1,650 volts. The DK.90A motor of 90 horse power at the one-hour rating on 550 volts, insulated for 1,650 volts, and the DK.30F motor of 56 horse power at the one-hour rating on 550 volts, insulated for 1,250 volts.

These motors are of our standard self-ventilated design, and whilst of different outputs are manufactured generally to the same specification. The motors are arranged for nose suspension and drive through single helical gearing having a helix angle of $7\frac{1}{2}°$.

Fig. 6. Armature of D.K. 91A Motor.

The gear wheels are of special cast steel accurately machined and heat treated, and the pinions are of high-tensile tool steel similarly treated. The gear wheels and pinions for the DK. 91 and DK. 90 motors are of the same gear ratio having 61 teeth on the gear wheel and 19 teeth on the pinion, the car wheel being 930 m/m in diameter when new. The gearing for the DK. 30 motor has a ratio of 81/17, the car wheel having a diameter of 860 m/m.

Fig. 5 shows a DK. 91 motor with gear case removed, and Fig. 6 a finished armature for the same motor. An interesting feature is that all armature bearings are of the Hoffman

roller bearing type. Suitable seals have been provided in order to prevent grease being drawn into the motors, and in service it has been found that the only attention the bearings require consists in adding a small quantity of pure mineral grease to the roller bearings every three to six months. The axle bearings are of the standard sleeve type, lubrication being effected by means of wool waste and horse hair packing drawing oil from a well and distributing it over the journal surface with which it is in direct contact through a window of large size in the bearing

The magnet frames are of the box type of high permeability cast steel, the armature bearing boxes and axle caps being separate steel castings. The pinion end axle cap is elongated and forms a supporting arm for carrying a gear case of pressed steel. Four main field poles of laminated construction are fitted. Auxiliary poles are provided to ensure good commutation on all loads, and the motors are capable of running in either direction from no load to 100 per cent. overload practically without sparking. Mica insulation is used on the armature and the main and auxiliary field coils.

The armature core plates are supported on a cast steel spider, between cast steel end-plates, and the commutator is built up on a separate spider which is carried on, and keyed to the main spider. By this construction it is possible to remove an armature shaft without disturbing the armature windings or commutator.

The English Electric Company has supplied to the railway company on a recent order 11 equipments each consisting of four DK.91 motors and camshaft gear for controlling them. For the metre gauge lines four camshaft control equipments each controlling four DK.90 motors have been supplied, and in addition 49 DK.30F motors for operation on another portion of the Company's system.

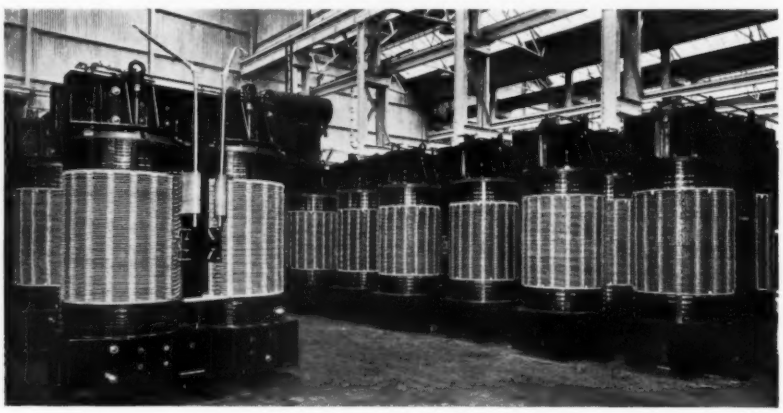
The total order therefore comprised:—

11—Standard gauge equipments.
4—Metre gauge equipments.
45—DK.91 motors.
13—DK.90 motors.
49—DK.30 motors.

and in addition a suitable stock of control and motor spares.

These equipments have now been in service for well over twelve months, and our customers inform us that the motors and control gear are operating very satisfactorily.

In conclusion our best thanks are due to the N.Z.H. Tramweg, Mtj., for their kind permission to publish the information contained in this article, and also for the photographs of the rolling stock in service.



View in the Transformer Shops, Stafford Works, showing:—

88,000 K.V.A.

of single-phase transformers for operation in 3-phase banks at

110,000 volts.

"English Electric" Truck Switchgear.

The general principle of truck type switchgear, although by now familiar to most people, is, briefly, that all instruments and gear required for the control of a particular circuit are accommodated on a truck running on wheels. Busbars and cable terminals are fitted in a fixed enclosure having openings into which the trucks " plug in." This arrangement has the broad advantage of complete enclosure when alive, and also of complete accessibility of the apparatus when the truck is withdrawn, and consequently dead. In addition it is extremely compact, and a system of locks, interlocks and automatic shutters renders it particularly safe and suitable for operation by semi-skilled attendants.

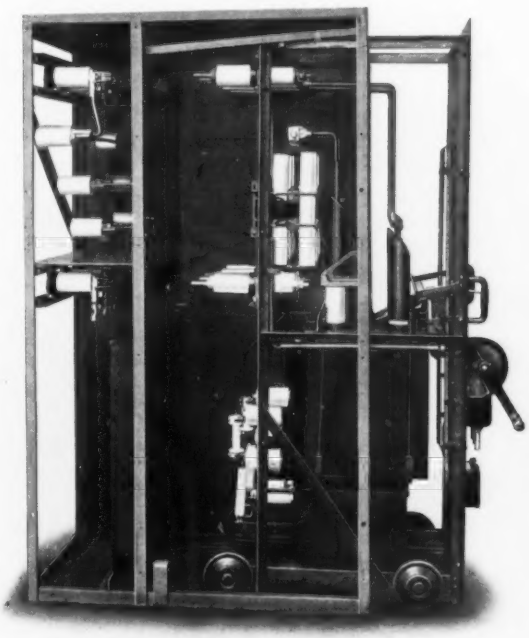


FIG. 1. TRUCK UNIT, WITH BACK AND SIDE REMOVED TO SHOW INTERIOR, AND TRUCK PARTLY WITHDRAWN.

Its chief application lies in substations and factories taking H.T. supply, and for these cases it is increasingly popular; at the same time, such is the flexibility of the system, that it can be adapted to almost any requirements, and is frequently used in conjunction with exciter pedestals for controlling alternators in small and medium stations. From both the manufacturer's and the user's points of view the gear is convenient to handle and assemble. The trucks are manufactured and shipped on the unit principle so that switchboards can be built up on site by simply bolting the units together and inserting the busbars, erection costs being thereby reduced to a minimum. Similarly new units can be added at any time with very little interference to existing gear.

" English Electric " truck type switchboards are extremely compact, and, as all gear and connections are accessible from the front, they can be placed hard up against a station wall without any passage-way behind. The space normally required in front of a switchboard for operating is sufficient for the withdrawal of the trucks. No special foundations are required beyond a reasonably level floor as the trucks, when being pushed home, do not run on the ground. Instead, the wheels run on special registering rails which engage with portions of the wheels which are never in contact with the floor, the trucks being slightly raised by the rails so that the wheels leave the floor.

Most substation floors in these days are of concrete, and on such a foundation the trucks can easily be made vermin-proof as there are no uncovered openings on the front, through which vermin could enter. A little trouble in this respect is well repaid, as instances

can be called to mind of serious trouble being caused by rats or mice.

In the illustrations, Figs. 1 and 2, will be seen the fixed portion of the truck unit carrying the busbars and fixed isolating contacts. These are screened by semi-permanent partitions which give access from the front when required. The busbars run from end to end of the switchboard through openings which at the ends of the boards are fitted with cover plates. Through these openings the engagement of the top set of plug contacts can be inspected from an adjacent cubicle. In order similarly to inspect the usually inaccessible lower plug contacts circular openings are provided, as shown in Fig. 2. These openings are covered by plates when not required.

The framework of both fixed portion and moving truck is constructed of sheet steel and angle iron, no castings being used which are liable to breakage in transport.

The movable truck carrying the circuit equipment has contacts which " plug in " at the top and bottom through openings near the back of the cubicle, which, when the truck is withdrawn, are covered by automatic shutters to prevent accidental contact. In Fig. 1 the truck is shown just about to enter the openings; one set of wheels, it will be observed, is running on the registering rails, the other set of wheels, near the front of panel, still running on the floor. An earthing contact is fitted on both movable truck and fixed portion, connected to an earth bar running along the top of the board so that the structure of the truck and the frames of all apparatus on it are automatically earthed when the truck is alive.

Substantial and effective mechanical interlocks are provided which render it impossible to withdraw or to replace a truck unless the oil circuit-breaker is open. A special feature of " English Electric " trucks is the provision of a lock of neat appearance for locking the truck in position instead of the unsightly padlock which is supplied by some makers for this purpose. The lock serves the dual purpose of locking the truck and numbering the circuit. Each lock bears a different number, the figures of which are raised in the key socket on the panel. The keys bear similar incised numbers which fit over the raised numbers in the key sockets so that only the correctly numbered key will fit in any particular lock.

" English Electric " truck units are made in two sizes covering a large number of ampere ratings and voltages up to 1,200 amps. low tension and 600 amps. at 11,000 volts. Trucks of the larger size are used for 11,000 volts, also for the higher currents at lower voltages,

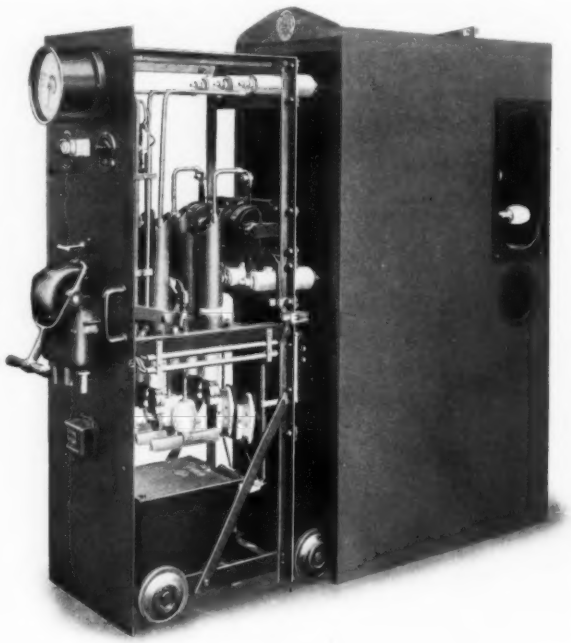


FIG. 2. SINGLE TRUCK UNIT WITH TRUCK WITHDRAWN.

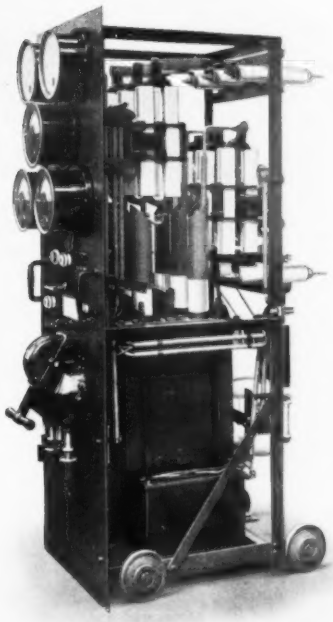


FIG. 3. TRUCK WITH EQUIPMENT FOR SPLIT-CONDUCTOR PROTECTIVE GEAR.

and occasionally for special equipments requiring a large amount of internal apparatus. The oil circuit-breakers in both sizes of truck are standard triple-pole units with our well-known patented spring tank suspension.

In order to economise space the potential transformer is mounted underneath the oil breaker tank, and is mounted on rollers to facilitate withdrawal. For the same reason the low-tension small wiring to the potential transformers is left sufficiently long to obviate the necessity for disconnecting it on withdrawal of the transformer. The only connections which have to be taken off are therefore the high-tension leads. The potential transformers are, of course, protected by high-tension fuses, which are mounted separately, and can, if required, be further protected by limiting resistances. These resistances have a negligible effect on the transformer accuracy, owing to the extremely small high-tension current flowing; in the event of a fault in the transformer they limit the rush of current until the fuse blows. They are particularly applicable for systems with a comparatively large amount of generating plant behind, on which a potential transformer failure might cause serious consequences.

The small wiring from current and potential transformers to instruments, relays, etc., is liable on trucks to become displaced and damaged and in order to obviate this risk it is run in firmly cleated fibre tubes which provide both mechanical and electrical protection, and give a particularly neat appearance. These tubes can be seen clearly in the illustrations and the absence of untidy wires and loose ends will be observed.

The fuses for the protection of the small wiring are of the "Zed" safety cartridge type in which only the correct size of cartridge can be used so that efficient protection is afforded to the instruments at all times. The fuses are now fitted practically flush with the board and black porcelain fuse caps can be supplied to match the general finish.

The front of the panel carries the operating gear, instruments, relays, etc., of which a comparatively large variety can be accommodated. The oil breaker operating handle, carrying overload and low-voltage trip coils, is of the entirely enclosed type, and as previously mentioned, requires no uncovered openings or slots in the panels through which vermin might pass. An inspection cover provides access to the levers and catches for the purpose of inspection and occasional oiling of the mechanism. When overload releases are employed, two are sufficient for all two-phase systems and for three-phase systems in which the neutral is not earthed. For three-phase systems with earthed neutrals, three releases should be fitted, and it is advisable in many cases to put in three releases on three-phase systems which are not earthed at the time, but which may in future have their neutrals earthed.

Overload releases may have time limit attachments, either fixed directly to the plungers, or in the form of separate fuses shunting the coils. In the first case the time element consists of a train of wheels driving an air vane which provides a retarding force varying with the amount of overload. Time limit fuses on the other hand are mounted in a separate case with a glazed window, and, by shunting the overload coils, reduce the volt-ampere consumption to a very small amount and allow more load to be put on the current transformers in the form of instruments. The fuses, therefore, are particularly applicable, and are usually recommended, when integrating meters are required on the same circuit. Both forms of time element have an inverse characteristic so that the heavier the overload the smaller the delay in opening the circuit-breaker.

In substations, it is frequently necessary to know whether pressure is on or off, although, since the pressure cannot be regulated, no numerical indication of the voltage is required. A simple form of potential indicator is often employed, which works on the electrostatic principle and is connected directly to the high-tension circuit without the necessity for a potential transformer. A device of this kind saves first cost and gives all the indication that is necessary.

The principle of the instrument is that the fall of potential along a tube of insulating material, has, generally speaking, an even gradient. A metal needle, pivoted in the centre of the tube with a slight bias towards

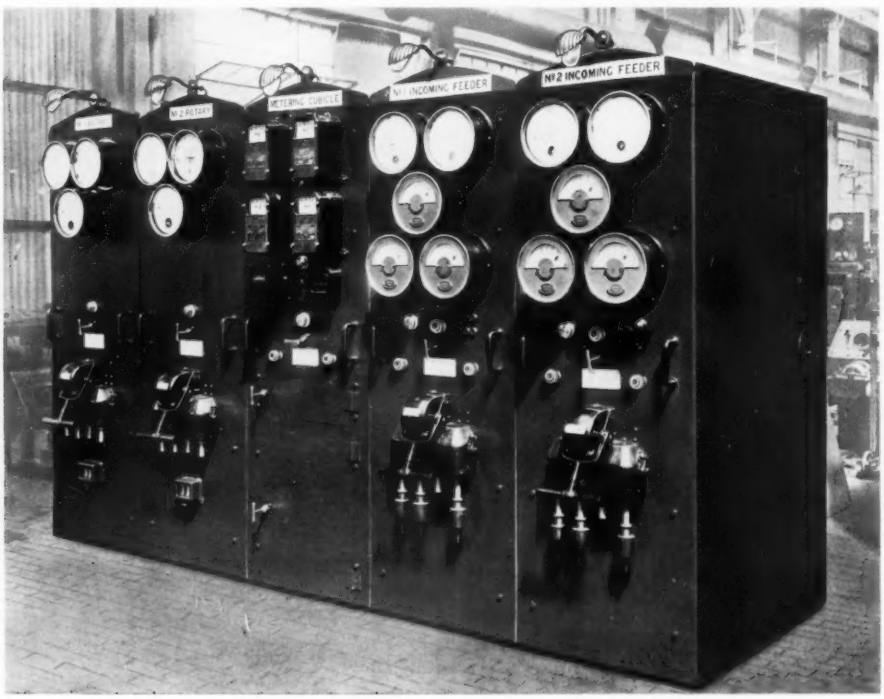


FIG. 4. TRUCK SWITCHBOARD FOR CONTROL OF ROTARY CONVERTERS AND 11,000-VOLT FEEDERS, WITH SPECIAL METERING CUBICLE.

one side, will, when the circuit is alive, experience electrostatic attraction between each end of the needle and the axis of the tube. If the needle is coloured white and a white line is painted down the front of the tube, pressure " off " will be shown by a broken white line, whereas pressure " on " will cause the pointer to become parallel to the axis of the tube, thus making the white line continuous. Potential indicators are mounted behind and clear of the front of the truck, the needle being visible through a glass window.

The design of " English Electric " truck-type gear is such as to allow considerable flexibility in the accommodation of instruments and also of the apparatus inside the truck. Truck units have been standardised for split-conductor protective gear in which two sets of current transformers are supplied, one set for protection and one set for instruments, as illustrated in Fig. 3. Merz-Price protection and many of the variations of this system can also be accommodated. Another important feature of the design is that duplicate busbars can be incorporated by increasing the height of the trucks, and various schemes of ring type sectionalised busbars have been supplied, a second set of bars being provided above the cubicles proper.

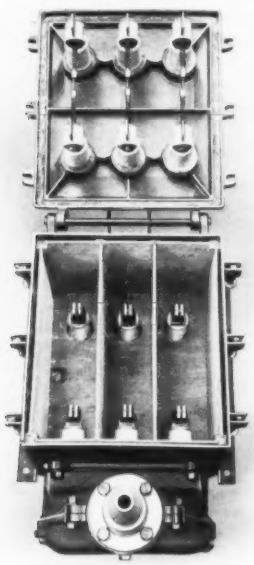


FIG. 5. OIL IMMERSED SWITCH-FUSE.

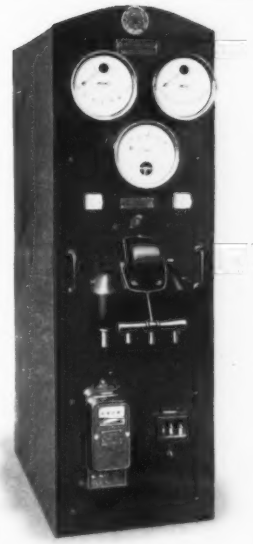


FIG. 6. SINGLE TRUCK FOR CONTROLLING 6,600-VOLT SUPPLY.

Variations are also possible in the position of cable boxes. The standard arrangement is to mount the trucks over a cable trench, each cable coming up from the bottom into its particular cubicle. In some cases, however, cable trenches are inconvenient, and where cables are run on cable racks along the wall or underneath the floor above, right-angle cable boxes are fixed at the back of the cubicles. In this case, of course, it is necessary to leave a certain amount of space at the back of the board for connecting.

With regard to accessories, swinging brackets with groups of busbar instruments or synchronising gear can be mounted at either end of a board, illuminating lamps can be fixed above and, in fact, the usual accessories of a fixed switchboard can be accommodated. Exciter pedestals carrying field regulator handwheels, field switches, discharge resistances and exciter instruments, although not part of a truck board proper, can be mounted in convenient positions for alternator control. Metering cubicles, either with or without busbar sectionalising, have been standardised to line up in size and appearance with the truck units.

Fig. 4 illustrates a board with two incoming feeders, metering and sectionalising cubicle and two rotary converter equipments. In this case the metering cubicle consists of a standard truck, without oil breaker, with the current transformers mounted between the plug contacts on the truck. Withdrawal of the truck, therefore, sectionalises the busbars. The potential transformer, however, is mounted in a separate screened compartment at the bottom of the truck so that in the event of a high-tension fuse blowing it is not necessary to withdraw the truck with consequent interruption of supply. By unlocking the upper of the two doors in the lower portion of the truck, the potential transformer isolating switches may be opened. The potential transformer is then dead and accessible by opening the bottom door.

For metering cubicles in which it is not required to sectionalise the busbars, the current transformers are mounted in the run of the busbars themselves, and a hinged door is provided in front of the cubicle to give access to the potential transformer and its fuses; these being isolated first in the usual manner.

In many cases, especially in substations, a small transformer is necessary for lighting the building and sundry other purposes. The cost of a completely equipped truck for controlling the high-tension side becomes very high in comparison with the cost of the transformer and a cheaper method is to connect the transformer to the high-tension supply through an oil-immersed switch fuse of the type illustrated in Fig. 5.

These triple-pole switch-fuse units consist, substantially, of a fuse on each phase, mounted between contacts fixed to the inside of the lid. When the lid is closed the contacts engage with fixed contacts passing through the tank; when the lid is open, the moving contacts, and consequently the fuses themselves, are clear of both the circuit and the oil. The fuse wire is comparatively small and is carried between spring-loaded plungers, which, when the fuse blows, are drawn rapidly apart, giving a long clear break for a small amount of volatilized metal. The cover is opened by a loose handle, which, when not required, is folded back flat against the top. The switch fuses are made in sizes up to 100 amps, and for pressures up to 33,000 volts, although, of course, they would not be required for more than 11,000 volts in connection with trucks. The rupturing capacity of these fuses is such that they can be used on quite large systems.

FIG. 7. 11,000-VOLT TRUCK SWITCHBOARD WITH BUSBAR SECTIONALISING UNIT IN CENTRE.

Power-operated Main Controller for Reversing Mill Equipments.

One of the functions of modern engineering is to reduce as far as possible the actual manual labour involved in the performance of any operation, and an interesting but important example of this tendency is the development of a main controller for reversing rolling mill work, whereby the manual labour imposed on the driver of the mill is reduced to a minimum.

In former practice it was usual to control the speed and direction of the rolls through the operation of a lever of the " signal " type, as is shown in Fig. 1, this lever operating the controller through rods and gearing. As it is necessary in the interests of safety to provide " dead man " control, i.e., to introduce means whereby the control lever is brought to the " off " position in the event of the driver's hand being removed, some device in the nature of a spring has to be employed against which the driver has to operate the lever; this entails a considerable amount of physical effort. The result of this is that towards the end of a day's operation, a slowing down occurs in the rate at which the mill is operated, and to overcome this a mechanical means has been devised for providing the necessary power, leaving to the driver only the duty of setting the position of a valve which controls the flow of the operative pressure fluid.

Fig. 1. Main Controller with Lever Operation.

The method employed embodies the use of an oil Servo-motor which is coupled directly to the spindle of the controller, and which, by the admission of oil to one side or other of a working piston, gives a movement to the controller arm in the one or other direction.

The employment of a direct drive from a " signal " type lever necessitates the controller itself being mounted adjacent to the driver which, in the case of a rolling mill, means that it must be erected on a bridge across the mill floor near to the mill itself, where it is subject to heat and, what is worse, dust of a largely metallic character. As the resistances of the controller must be ventilated there is the risk that certain sections may become short-circuited due to the presence of deposited metallic dust, and in addition, the wear on the main contacts is considerably increased owing to the grinding action of these metallic particles between the contact faces and the copper brushes.

With the use of the Servo-motor mentioned above, remote control can be adopted for the necessary valve setting with the attendant advantage that the controller itself can be mounted in the Motor House where it is protected from both heat and dust.

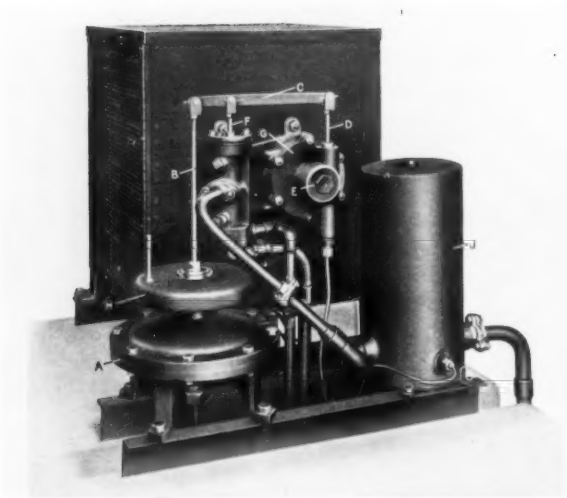


FIG. 2. BACK OF NEW TYPE OF CONTROLLER SHOWING OPERATING MECHANISM.

In Fig. 3 is shown the front view of a controller of the new type with the cover removed so as to expose the contact studs, rings and operating arm. As will be seen, the design follows that of the ordinary face plate controller, the slate base carrying the contacts being reinforced electrically by mica plates beneath the rings.

The inner contact segments control the voltage applied to the armature of the Mill Motor, whilst the outer segments weaken the field of the motor to give the higher portion of the speed range.

The control arm moves in both directions through an equal angle giving a forward or backward rotation to the Mill Motor.

The reverse view of the Controller, Fig. 2, shows the operating mechanism, the various portions of which are as follows:—

A diaphragm contained in the chamber A is connected to rod B attached to one end of rocking lever C, which has its other end connected by rod D to a rack actuated by a pinion in chamber E. To a suitable point on the rocking lever C is connected rod F which operates the valves admitting oil to the one or other side of the Servo-motor G.

The diaphragm A is controlled by a duplicate diaphragm on the driver's platform, a single play pipe filled with a water alcohol mixture connecting the two.

By means of a small actuating lever the diaphragm on the control platform is raised or lowered at will, and an exactly corresponding movement takes place on diaphragm A. This movement raises or lowers the valve admitting oil under pressure to one side or the other of the Servo-motor. This produces a move-

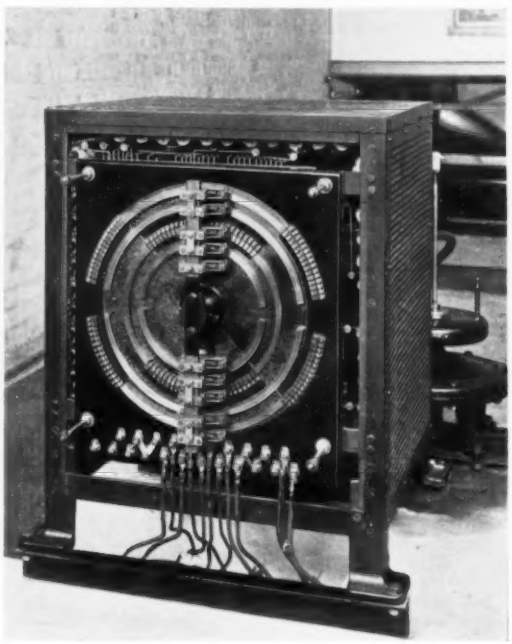


FIG. 3. POWER-OPERATED CONTROLLER WITH COVER REMOVED FROM FACE-PLATE SWITCH.

ment of the control arm, and as this movement takes place the resetting device E operating on rod D brings the valve back to the central position, cutting off the oil supply from the Servo-motor. This device ensures that the position of the control arm corresponds to a definite position of the driver's lever under all conditions.

The reservoir H is partly filled with mercury to a height which compensates for the difference in level between the driver's platform and the controller itself, and the weight of the mercury column counter-balances the water column in the play pipe.

An air receiver J is inserted in the incoming pressure oil pipe and acts as a steadying device, whilst at the same time, should the pressure oil fail, it will provide the necessary reserve to bring the controller back to the "off" position.

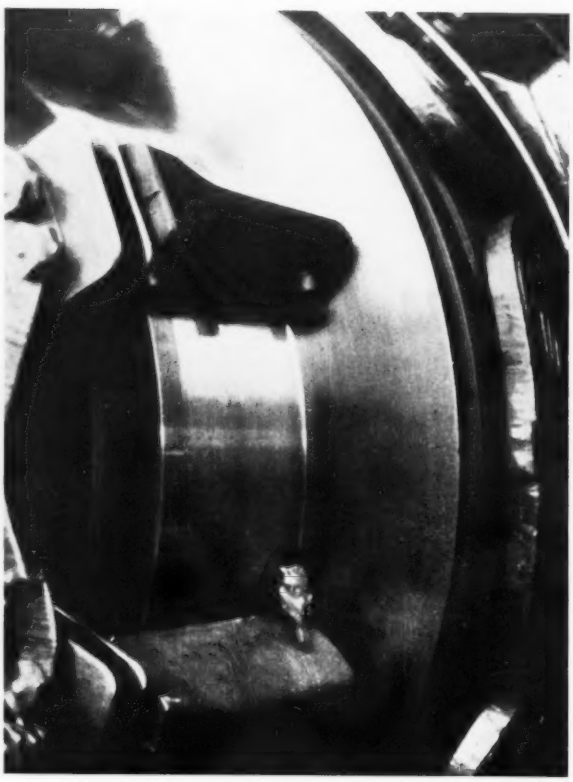
For actuating the Servo-motor, oil at a pressure of about 30 lbs. per square inch is provided from a small gear type pump, which can be driven in any suitable manner.

As the Mill Motor itself can only be operated at such times as the fly-wheel Motor Generator Set is running, a pressure pump can quite well be driven by belt from this portion of the equipment, but to ensure a stand-by supply in the event of belt trouble, an additional motor-driven pump feeding into the same pipe line can be fitted, and it is usually considered desirable to adopt this course.

Fig. 4 is a view of the driver's station on a large reversing mill installation equipped with the new type of controller, and shows the desk with speed indicator and electrical instruments and the small operating lever for the controller which is situated elsewhere.

FIG. 4. INSTRUMENT DESK AND DRIVER'S LEVER FOR POWER-OPERATED CONTROLLER.

The first controller of this type has been in continuous service for over 12 months, the number of operations when in use being at the rate of 8 to 12 per minute. During that period it has given complete satisfaction, and a number of similar equipments have now been installed and are under construction for other large reversing mill plants.



This illustration has been made, with no retouching, from a small snapshot photograph received recently from New Zealand. In the Otira Power Station of the Midland Railway, the electrification of which was described fully in the January, 1925, number of this Journal, there are installed two "English Electric" 1200 K.W., 1500-volt geared Turbo-generator sets, and when one of these was on a load of nearly 1300 K.W. it was noticed that a sparrow had perched on one of the brush arms.

"English Electric"

WINDING PLANT

No 1 Winder.

Synchronous Motor Converter Sets.

A TYPICAL "English Electric" Winding installation at a Colliery in South Wales comprising two Winders; No. 1 to deal with 250 tons per hour. and No. 2, 450 tons per hour, the depth in each case being 1,950 feet.

No. 1 Winder has one and No. 2 Winder two direct-coupled D.C. Winding Motors each with an output of 1,400 B.H.P. at 51 R.P.M., the combined output for No. 2 Winder being 2,800 H.P.

This is the largest Electric Winder in this country. The control is on the well-known Ward Leonard system. The motors driving the converter sets are of the salient pole synchronous type fitted with automatic Power Factor correcting device.

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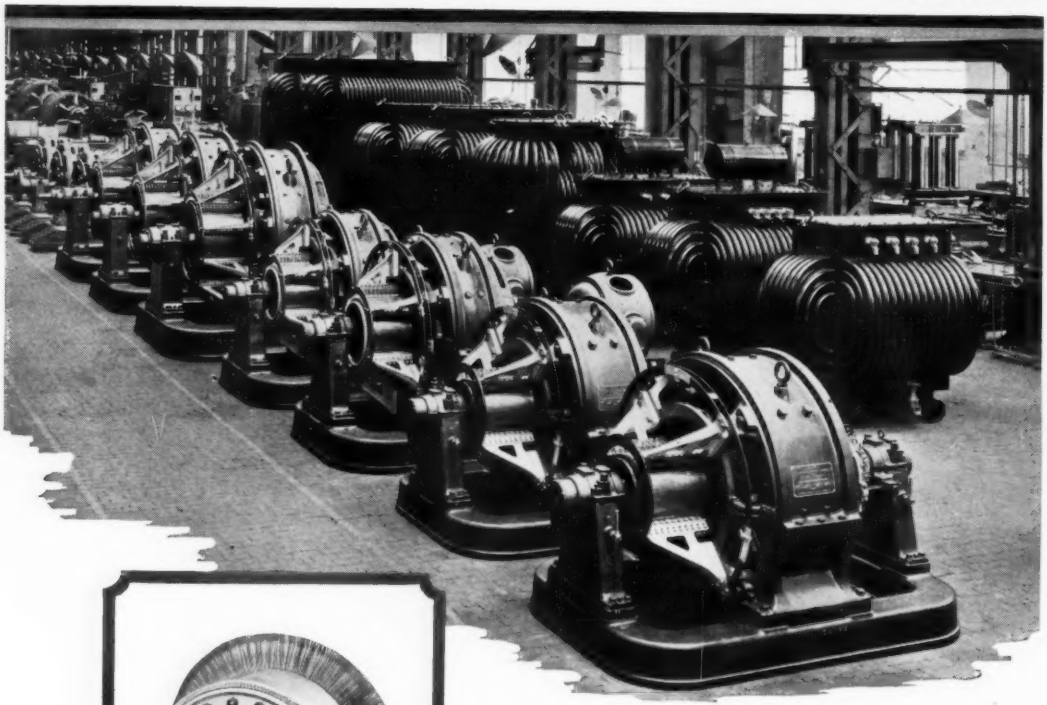
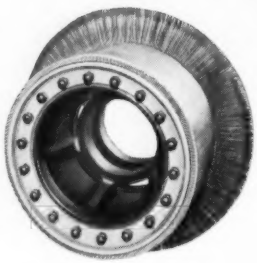
"English Electric"
ROTARY CONVERTERS





Commutator of 1,500 K.W. Rotary Converter.

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"English Electric"
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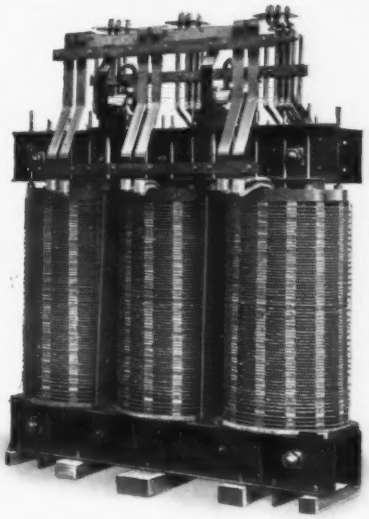
WATER COOLED TRANSFORMER
5,000 K.V.A., 3-PHASE, 50 CYCLES
37,000/6,000 VOLTS, DELTA/STAR



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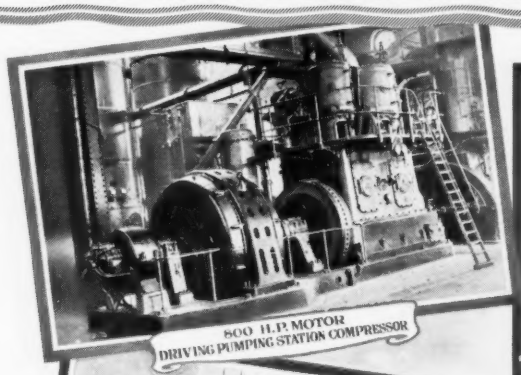
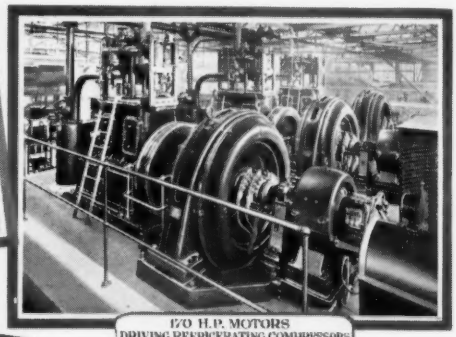
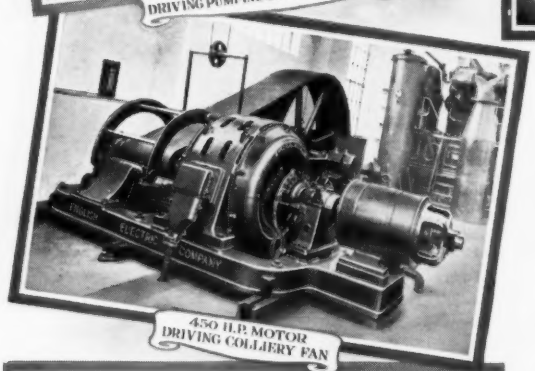
MOTORS *for* POWER FACTOR CORRECTION



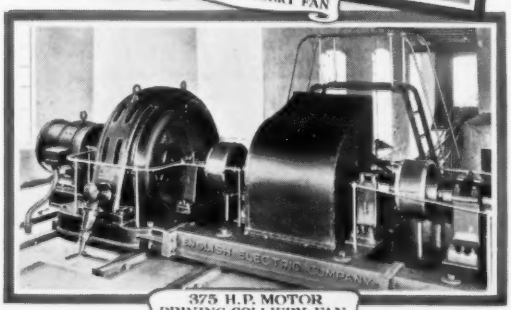
800 H.P. MOTOR
DRIVING PUMPING STATION COMPRESSOR



170 H.P. MOTORS
DRIVING REFRIGERATING COMPRESSORS



450 H.P. MOTOR
DRIVING COLLIERY FAN



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